POWER PLANT ENGINEERING

GENERATION, TRANSMISSION AND UTILIZATION OF STEAM, ELECTRIC, DIESEL AND HYDRAULIC POWER

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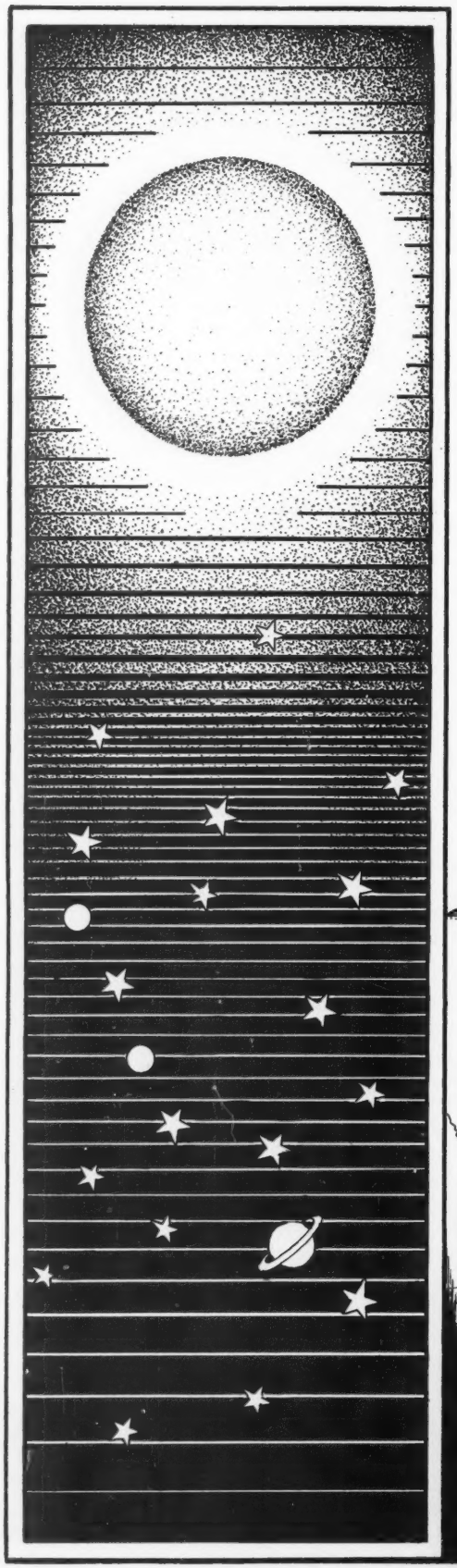
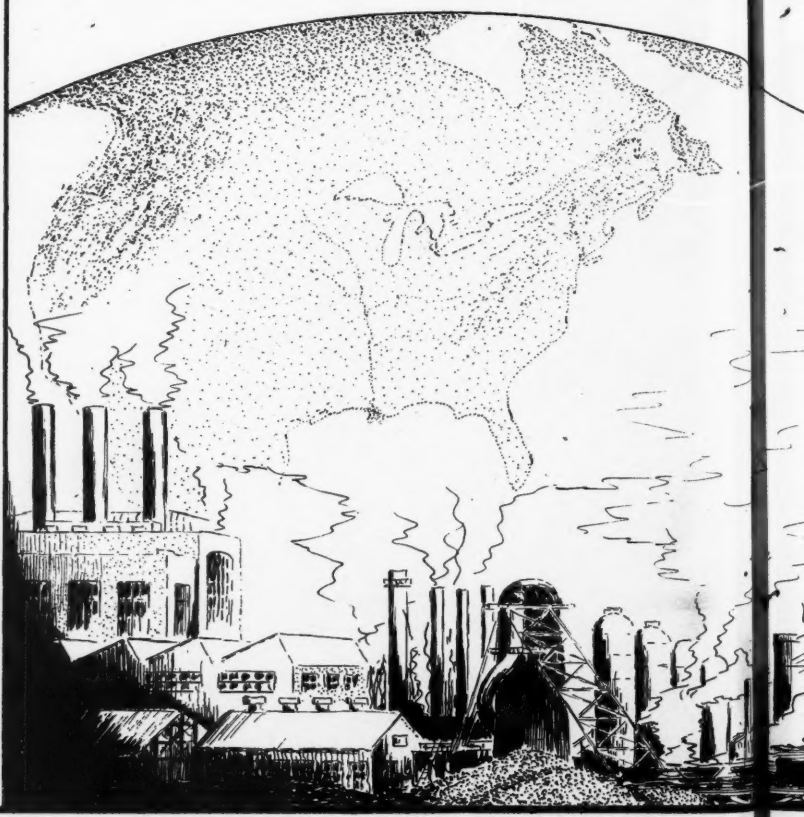


ALL POWER S

ASIDE from the particular piece of work done on the solar system in the beginning, perhaps by a wandering star, all earthly energies step off from the sun. To the sun we owe everything; all our resources, all our motion, our environment, the growth of our plants, past and present, the biological processes in our bodies—all these things are conditioned by the sun. The heat developed in our pulverized-coal fired boilers is as much power derived from the sun as is the energy which actuates a photoelectric exposure meter in the summer sunshine.

The latter represents a direct use of the sun's power but most of our use of solar energy is indirect. Of the indirect solar energies there are two kinds; the physical, such as the power of the winds, waterfalls, solar tides and waves; and the chemical energies in the oxidation of carbon and hydrogen stored by the sun's energy in plants. Of the chemical energies, those resulting from internal oxidation refer to foods and those resulting from external oxidation refer to fuels. Of the fuels there are natural gas, liquid petroleum, vegetable oils and alcohols. And in the solid fuels we have coal, old and limited in amount, and wood, modern and continuous in supply. Such, briefly, is an inventory of the energies available to man but all of them have their origin in the energy of the stripped atoms in the sun. This earth is sun in matter, in dynamics, in energy and in destiny.



R STEPS OFF FROM THE SUN

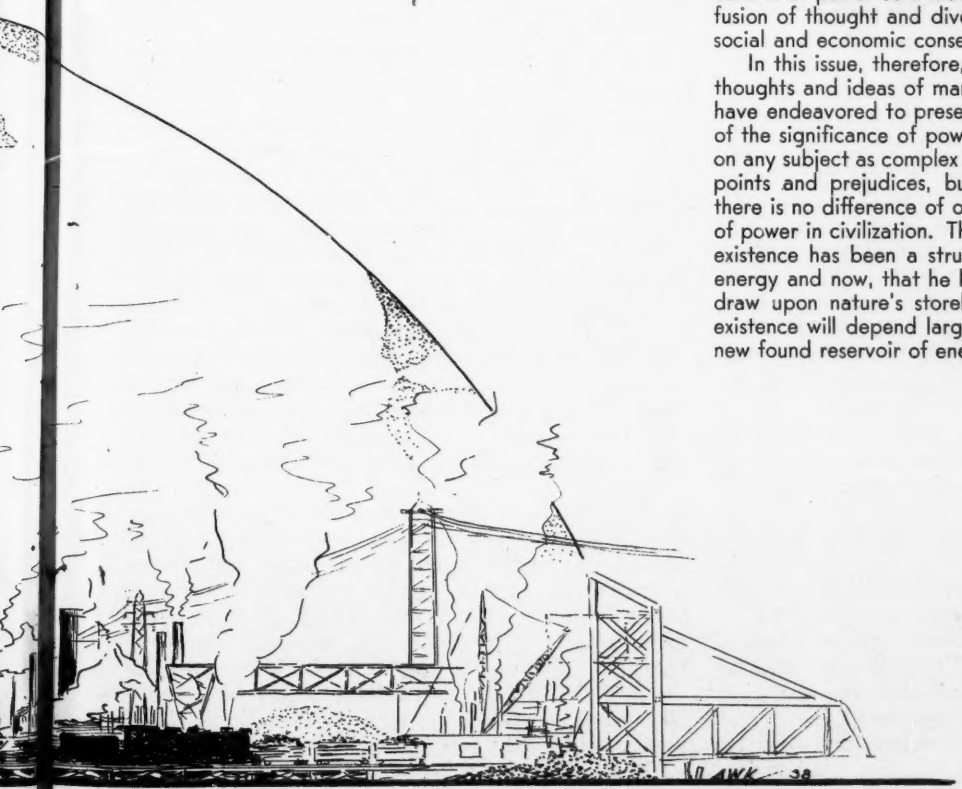
While it is interesting to trace the course of the solar energy from its 40 million degree origin in the atoms of the sun through space to this planet, in this issue we are primarily concerned with man's use of the sun's energy upon earth and in the pages that follow we will endeavor to describe how, by his increasing knowledge of power, man has been able to survive and to rise from a brute animal to a rational being, capable, between limits, of controlling his environment and of directing the energy of the sun to his use—or misuse. Further than that, we shall try to present a picture of the sort of world man has made through this increased use and knowledge of power—how, by harnessing the power of rivers and releasing the energy of the fossil fuels laid down by the sun millions of years ago, he has made it possible to do away with drudgery and to travel and communicate over the entire world with great speed. And, finally, we shall endeavor to show how these technical advances, beneficial as they might be, somehow have introduced problems of a social and economic nature which man has not yet been able to solve.

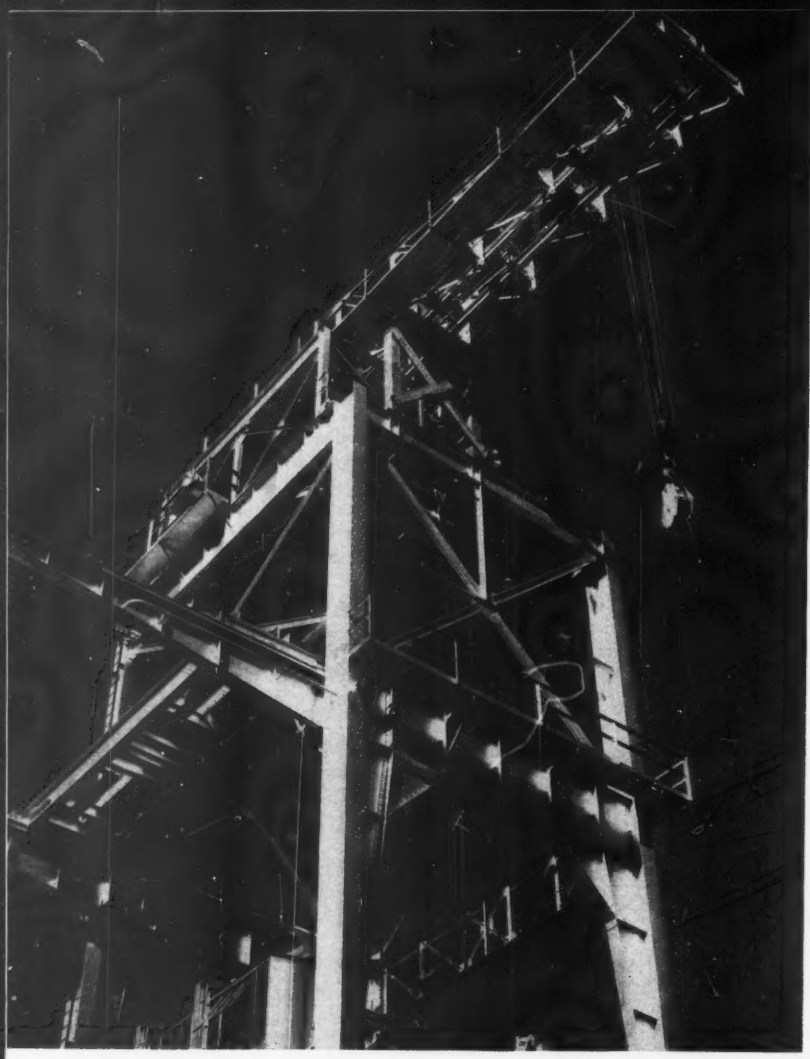
For, though man has learned how to put nature's storehouses of energy to work he has not succeeded in adjusting his existence to the new environment created by the very forces he has released. Despite his knowledge of stripped atoms and energy-mass transformations, man is still a creature of the earth; he must still conform to the laws which nature has laid down. Man may harness the power of mighty rivers, he may turn the fossil fuels into dynamic electric power, he may encircle the world with marvelous transportation and communication systems and he may delve into nature's mysteries and synthesize her most complex products but when all is said and done, when new laboratories stand on every block and have solved every problem put to them, man will still remain a child of nature, living by sufference of her forces which he can adjust but cannot change. And, as Stuart Chase so aptly put it at the last World Power Conference, "if he cares to go on living in this world and his children after him, there are certain things man can do only at his peril." One of these things incidentally, and perhaps the chief of them, is to violate indefinitely the balance of nature.

This restriction upon upsetting the balance of nature has always existed but until man acquired proficiency in utilizing large quantities of natural energy there was little he could do that would react greatly to his detriment. Today, however, in tapping nature's vast reservoirs of energy man is able to change the face of the earth literally as well as figuratively on a scale never before possible, and his chances of upsetting nature's balances are greatly enhanced.

It is because of these fundamental implications in man's use of external power that we will find it of interest to consider these matters seriously and dispassionately from many angles. While the present generation accepts our control of power as a matter of course there is much confusion of thought and divergence of opinion regarding its social and economic consequences.

In this issue, therefore, we have gathered together the thoughts and ideas of many persons upon this subject and have endeavored to present a reasonably accurate picture of the significance of power in the world today. Naturally on any subject as complex as this there are conflicting viewpoints and prejudices, but whatever disagreement exists there is no difference of opinion regarding the importance of power in civilization. Throughout all history man's entire existence has been a struggle for the control and use of energy and now, that he has finally discovered the way to draw upon nature's storehouses of energy, his continued existence will depend largely upon how wisely he uses this new found reservoir of energy.





The Social

EDGAR ALLEN POE'S story of The Purloined Letter is based upon the idea that a fact can be so obvious that its existence is quite overlooked. In our daily lives, we usually accept the fact of power and what it does for us without grasping its meaning, or the change that power has made in the social and economic structure of humanity.

It is the purpose of this issue to study and try to analyze the facts about the production and use of power, its effects on human welfare, on the organization of society and industry and on government policies. This is not an easy task. For, although the physical aspects of power generation and use are comparatively simple, its effects on social, cultural, economic and geographical organization of mankind are complex and difficult to trace.

On the physical side, the facts of equipment and method are easily ascertained and classified. Certain natural laws have been discovered and applied and the effects due to this scientific progress can be traced. But man's reactions are complex and the endeavor to analyze the effect of technological progress on his life and welfare is complicated by sociological and economic theories and assumptions.

After all, man is an energy-driven organism for converting heat into thought and action. Society is a correlation of such human machines and its activities are a dynamic process. The effectiveness of this process is the ratio of results accompanied to effort expended and, in some aspects this seems low when comparing existing with ideal conditions, and actual achievement with the amount of effort expended. The lack of efficiency seems to be more on the side of developing effective, logical thought processes, since progress in physical activities and the use of power has been fairly continuous, even though there have been at times periods of stagnation.

Physical laws have been discovered and applied to promote material welfare, as the demand for more power was manifest. Conversely, as increased use of power was found to raise the standard of living, appetite for the use of more power increased. Major steps in advancement toward civilization are stated by Baker Brownell as: Use of fire; bow and arrow; domestication of plants and animals; weaving and basketry; pottery; use of metals; writing; use of energy from expanding gases and vapors; electrical transmission of power. This, or any other list of stepping stones of human progress will show increase in effective use of energy, muscular, mental and mechanical, to get work done with greater economy of effort.

Often these gains in energy utilization have made the difference between extinction and survival of a race, or between rise or fall of an existing civilization. Unfortunately, in early applications of energy—building, water supply, war making—since capital in the form of money or control of human labor (slaves) was necessary for developing projects, the resultant benefits were appropriated by the rulers and were of little value to the masses of the people. Progress made was therefore lost when these rulers were overthrown by revolt or by invasion from less advanced countries. Best use of power for the advancement of man has been developed where the people have dominated government and have the intelligence to utilize power and encourage its development.

Conceptions of methods of using power have often preceded application, having to await the development of necessary materials and devices. Hero and Branca early had the idea of impulse and reaction turbines, but development awaited the advent of strong materials, high-pressure steam and the need for large amounts of power. Leonardo da Vinci conceived the idea of flying and the use of the aeroplane, but no suitable power was available to drive it until the high-power, light-weight gasoline engine was developed.

While all social changes cannot be interpreted in

Implications Of Power

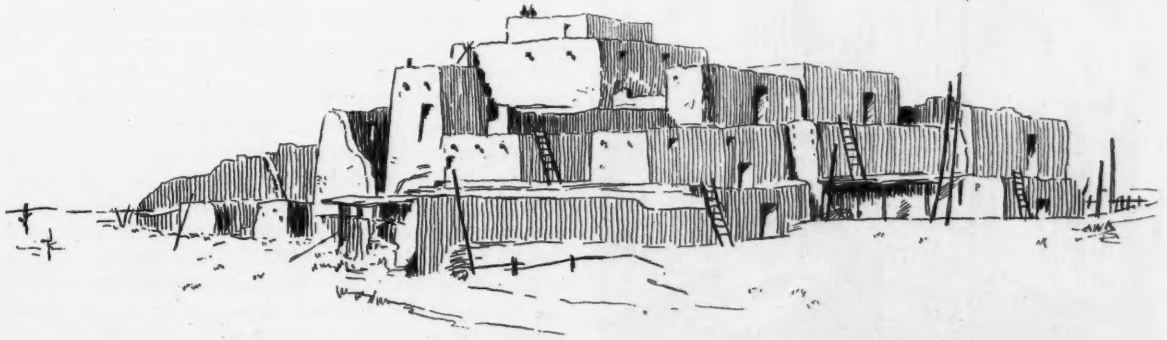
terms of physical power, a significant measure of human progress is the increase in use of power and the better conversion of bodily energy into reasonable thinking instead of brute force or wishful theorizing. Failure to recognize the intelligent use of dynamic resources, personal and general, as the basis of permanent civilized progress accounts for many of the haphazard and ineffective plans and actions of economists, sociologists, politicians, business men and even engineers. It is significant, however, that moral and ethical standards, the conception of the brotherhood of man, have originated and developed with the gathering of men into communities, and community life has been possible only by the use of considerable amounts of energy. Water supply, sanitation, transportation are essential in a community of any size and involve the use of power. Compare the conceptions of personal and property rights in countries inhabited by roving tribes with the regulations and laws in modern cities. In the former, might makes right. In the latter, the majority respect the rights of others, even though conditions are complicated by a minority which still has the ancient clan and tribal viewpoint.

Of the significant steps in human progress given by Brownell, each is greater than the preceding, since the effect is cumulative. Although but two of these were made in what we term historic times and have to do with power as we now think of it, the resulting progress has been greater and more rapid than during all the thousands of preceding centuries. Use of expanding gases as a source of power began the "machine age" and electrical transmission of power brought in the "power age". It is important to distinguish between these, since growth in the availability and use of power due to electrical transmission has resulted in changed conditions and created social, economic and political problems which were non-existent even a few years ago. Sociological and political thinking must be based on the new conditions if we are to adjust ourselves to the new environment and avoid mental, economic and social errors. The new environment is the result of bigger and better machines, wide application of power to human activity—results not possible without electrical distribution and which vitally affect economic and social organization.

Before the machine age, man's tools—wedge, screw, lever, wheel and spring—were associated with the use of muscular energy. The notable exception was the use of wind power to replace man power primarily for boat propulsion. This had a tremendous influence on standards of living and distribution of population. By its use the Phoenicians rose to a dominant place in the world trade, trade expanded, human relations diversified, the Americas became a part of world economy. Then came the mastery of expanding gases. First gunpowder to force a projectile (piston) to a distance; next attachment of a rod to the piston to convert linear into rotary motion; then the application of vapors and explosive fuel mixtures to driving the pistons. All this took much time and experiment but, in its development lay the foundation of the machine age. Previously, even in the use of water power, man mastered only small amounts of energy. But, with the use of steam and combustion engines, he became vigorously aggressive in his attack on Nature's storehouses, which soon brought about fundamental changes in his pattern of living.

Large amounts of power were developed but were localized. Congested centers for use of power resulted, with a new division of social and economic groups whose interests became diverse, rather than common as they were when agriculture was the predominant human activity. That factory production resulted in excessively long working hours will hardly bear analysis when those hours are compared with the conditions on farms, in homes and in home workshops even of today. In the development of factory manufacture by the use of power the trend has been steady toward less labor, more leisure and better working conditions, even though struggle has been involved in attaining these results. In the effort to get largest results with least labor, the initiative has naturally been taken by those with the keenest and most alert minds and they have profited thereby.

Roughly, two methods are available for distributing and utilizing power—mechanical and electrical. The former required the use of power in large blocks near the place where it is generated. The result was concentration of population near the factories and growth of industrial cities with consequent social and economic



problems. Man's ability to produce goods was multiplied, products were standardized for mass production, means for distribution were organized, machine operators were developed in place of individual artisans.

Application of power to the bettering of living and working conditions was negligible but the standard of living rose because of availability of factory products and the rapid transportation of goods and people. To a degree these conditions persist and the social and economic problems are not yet solved, but they are recognized and solutions are gradually evolving.

Development of electrical transmission, the next great step in the rise of power, made possible concentrated generation in large amounts with wide distribution, and division into small blocks for consumption. Also it made possible the new type of mobile machine. This may have a single motor usable wherever an electric circuit is found; or it may be a complicated machine with many motors, controlled individually or by an interlocking and coordinated control system.

Organization and arrangement of factories was revolutionized; power became available for small factories at widely distributed points and for farms; machines could be brought to the work. Production increased enormously; labor required for operation of machines was reduced; shop conditions were improved; manufacture could be decentralized. Application of power to improve living conditions became available in offices, shops, institutions and homes, bringing a complete reorganization of methods and standards of living and in viewpoint of normal requirements for living.

Use of power jumped ahead. For industry as a whole and considering productivity in 1919 as 100, the productivity in 1921 was 134; in 1923 was 147; in 1925 was 155; in 1927 was 175; in 1929 was 188; in 1931 was 210. For later years, Brookings Institution gives the increase from 1929 to 1933 as 25 per cent, and Alexander Hamilton Institute gives increase from 1933 to 1935 as about 15 per cent. In the domestic and institutional field statistics are less definite, but increase in the sales of electrical appliances, refrigerators, ranges, washers, air-conditioning outfits, will easily show the influence of cheap available power on living conditions. From 1930 to 1937 the domestic customers of utilities increased from 19,880,000 to 21,600,000 and the kw-hr. per year per customer from 548 to 797, the cost per kw-hr. dropping from 6 cents to 4.37 cents. For the same period, farm customers in the eastern states doubled and in the western states increased 51 per cent; annual consumption per customer increased 1.42 times in the east, but decreased 23 per cent in the west, the annual expenditure for power per customer decreasing 5.5 per cent in the east and 30.6 per cent in the west.

Paralleling the development of electrical distribution came development of the internal combustion engine, also giving wide availability of small amounts of power and great mobility. Thus arose individual plants, portable machines where no electric lines were available, automobiles and trucks. While not a competitor of the large generating and distributing systems, the combustion engine provides for power generation in moderate and even large amounts and has greatly increased power use, especially in the field of transportation, has made mankind more power conscious and power dependent, has raised the standard of living and increased the range of human desires.

In the early development of the machine age, effort was centered on increase of production rather than on saving labor. There was no attempt to allot the benefits from the use of power reasonably among machine owners, management, workers and consumers. The result was struggle to overcome this condition. That struggle still persists, although it is self evident that to get the greatest benefit from the use of power requires cooperation among investors' management and workers with due consideration of the consumers. Wide application of machinery and of power to displace muscular effort aroused opposition of workers who felt that they were displaced and this has been increased by the wider use and control of machinery by automatic means ensuing on the electric transmission and utilization. Also desire for larger income has grown in order to enjoy the advantages of application of power to living. Increased use of power has brought problems as well as benefits.

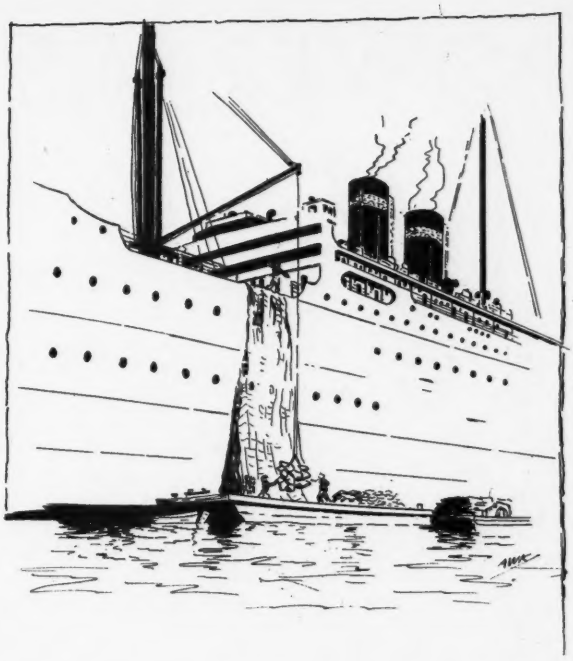
It is a dynamic age. Railroad, automobiles, steamships, airplanes, factories, canned and refrigerated foods, telephones, radios, electric kitchens, air conditioning—all require power to serve us. Our grandfathers had less than 1 hp. per capita; today the world has 25 to 100 hp. per capita in its various countries and localities. Under such conditions, ownership and use of the chief sources of power, coal and water power become of vital consequence, the struggle for

control leading to economic, social and political disturbances which are unsettling to industry; some form of fair adjustment is needed. Through the years, by the development of power resources, the world has acquired the means to meet its requirements as to food and manufactured products; yet some call this a mistake and advocate return to hand and muscle methods, spite of the fact that the present standard of living could not be maintained under those methods and that the claim is made that considerable portions of the people are not yet adequately housed, clothed and fed. Brookings Institution stated that in 1929, 90 per cent of our population could not afford a liberal diet and that consumption of manufactured goods should have been 84 per cent higher than it was. Production capacity was available, but, through faulty economic organization, advantage was not taken of this capacity. It would seem that the mistake is in the utilization of our facilities, not in having them.

Since records show that employment and wages have advanced most in industries where technological progress has been greatest, it would seem that more scientific development and use of power are indicated in the less progressive fields, rather than any backward steps. For the ineffective use of productive capacity, some blame capital, some blame labor, others blame politicians and some accuse the munitions makers. Regardless of where the blame may be placed, there remains the fact of an enormous increase in the dynamic effectiveness of our civilization in converting human energy into productive results.

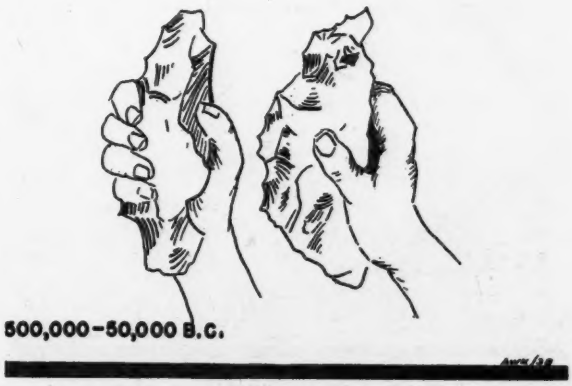
In cost of goods to the consumer are included overhead on the investment in buildings and machinery; cost of operation, including management, labor, power and upkeep; cost of distribution, covering selling and transportation. By increasing investment in machinery and the cost of power used, labor cost can be reduced. Yet, for workers displaced, employment must be found. Other productive industries must be created or these workers must be absorbed in nonproductive occupations such as selling, transportation or service. If they are transferred to selling and transportation, these costs of distribution, already overlarge in comparison with the cost of production, may so rise that cost of product to the customer will be increased, even though production cost is lowered. Thus increase in the use of power brings, along with its benefits, economic and social problems not easy of solution.

With many, the obsession persists that the returns from any industry are fixed and that the struggle must be as to the division of those returns, rather than the aim should be, by cooperative effort, to increase those returns so that all may have more to share. In this contention, as well as in provision for temporarily displaced labor until it can find employment, the politicians enter, bringing taxation and struggle for political advantage, with differing policies as to government control of industry or operation under free enterprise. Thus, into the problem of effective use of power enter politics, economics, sociology—practically all human activity. Yet, without the large use of power, human advancement to its present



level and maintenance of our present standard of living would be impossible. Power is a fundamental necessity to mankind, if our present civilization is to exist.

Use of power-driven machinery calls for mental development—knowledge, alertness and concentration—rather than for muscle and endurance. Mental ability rather than muscular is in demand. By what adaptations of power can we best utilize the services of those whose abilities are muscular rather than mental? How can their opportunities be increased? Here is an opportunity for engineers and those engaged in the power industry to lend a helping hand in the solution of social and economic problems. To give effective aid, social, economic and political factors must be considered as well as engineering and engineers must become interested in these factors. Engineers are trained and accustomed to logical thinking and disinterested action and should take active and prominent part in solving these problems, which is necessary if industrial and social stability are to be ensured.



Eoliths—Man's Earliest Tools

POWER AS A PRIVATE

A critical consideration of the various elements involved in the private ownership of the electric utilities and a comparison of the relative costs of private and government capital used in financing the development of private power systems as compared with those built by the government.

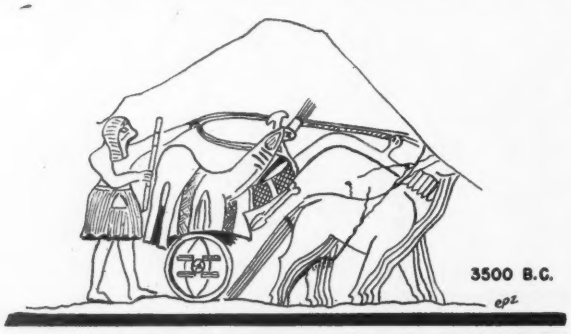
BY C. W. KELLOG
President, The Edison Electric Institute

BEGINNING with the modest million dollars which was the capital of Edison's first New York City lighting company in 1882, the electric power industry has become one of the largest private employers of capital in the United States, with an investment of upwards of 12 billions.

At the present time there are 27½ million customers of electric service, the installed capacity of prime movers in power plants producing electricity for public use totals 50 million horsepower and two-thirds of all machinery in mines and in industry operate on electricity produced from utility lines.

Building up the investor confidence necessary to attract the necessary amount of capital has been fully as arduous a task as the engineering skill required to produce the physical plant or the commercial effort needed to educate the public in the use of the product. Such investor confidence is the prerequisite to the continued expansion of every line of industry and it goes without saying that once, for one reason or another, this confidence is impaired then industry —and all who are dependent on it—stagnates.

It has often happened that those who have very little capital rail at paying others for the use of their capital. This frame of mind, wherever it has existed, overlooks two fundamental points. First that, as in the case of the utilities, in our complex modern world, labor can find nothing at which to work until some capital has been transformed into plant to make labor productive; and second, that capital itself is nothing more than the saved-up labor of the past—that part of the product of past labor which its owner has had the self-denial and character to save and set aside for the use of others.



Earliest Known Illustration of a Wheeled Vehicle

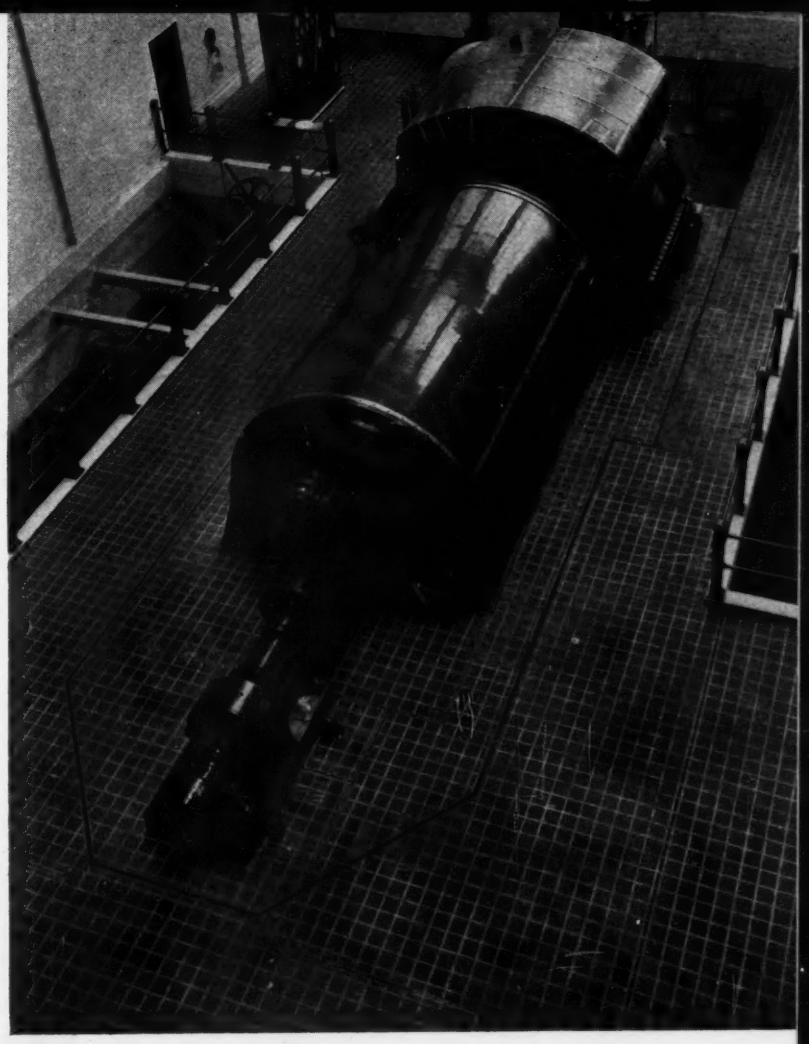
Anyone who has lived for years in the relatively undeveloped parts of the country knows from actual observation what capital hunger means to the small struggling community and how slow and painful is the process of getting those who possesses this capital (which can be transformed into useful wealth-producing tools) to invest some of it in their midst. This sort of pioneering work, of getting capital from its large reservoirs in the centers of population to work in the more sparsely settled areas, has been peculiarly the task of the utility companies during most of their history. It has meant bringing useful and drudgery-saving electricity to millions of people in this country in communities whose economic status was such that they would not, but for the utility, have been able to get that service unaided.

It is, however, the view of a large section of America in thinking about utility matters, that while it is necessary and proper to pay for the current cost of labor and material which have to be purchased from day to day, they may forget or scorn the return to the people who have furnished the capital to make the whole thing work. For it must not be forgotten that until someone has first put up the money to build a utility plant no one can be employed to run it and no earnings can be obtained from it to pay for anything.

No one would seriously claim that he ought to be able to rent a house from a landlord by paying the maintenance charges and taxes, without any return on the owner's investment. Anyone knows that if landlords could not get a return on the investment in the houses they erect, the supply of new houses would soon stop. Rent forms about 15 times as large an item in the average family budget as electricity, yet somehow many people have been asked to believe that the return on someone else's investment, which is admittedly and inevitably the largest part of house-rent, becomes an unholy thing when the money is invested in plant to produce electric service.

The same principle runs throughout our entire economic structure. Every farm, mine or factory

INDUSTRY



The Latest in Central Station Practice. Looking down on the new 40,000 kw. 3600 r.p.m. Turbine Generator recently installed in the South Meadow Station of The Hartford Electric Light Co., at Hartford, Conn.

represents someone's capital, which its owner would not have put into the enterprise in question unless he believed that those who bought its products would pay, among other things, for a fair return on the use of his capital for that purpose.

The public utility company is particularly vulnerable because of the exceptionally large amount of fixed capital required to furnish the service. The ratio of fixed capital to annual gross receipts is seven times as great for electric utilities as for the average industrial enterprise, so that while the central station industry ranks third among the industries of the nation in point of size of investment, it stands well down the list in point of value of its annual product.

The relative magnitude of the investor's stake is indicated by the following analysis of earnings:

For the year 1937, the dollar spent by the consumer in purchasing electric service was divided in the following proportions:

Distribution of Revenue in 1937

(Total approximately $2,055,000,000)		
Power (fuel alone 8.4%)	13.0%	
Transmission and Distribution	8.2%	
Commercial and New Business	9.0%	
General Expenses	7.5%	
Total Operating and Maintenance		37.7%
Taxes		16.1%
Depreciation		10.5%
Balance for Return on Investment		35.7%
		100.0%

These relationships show that power production alone (exclusive of fixed charges) amounts to but 12 per cent of total costs, that all operating expensse, including power, aggregate but 37.7 per cent, that relatively fixed charges amount to 62.3 per cent and that the balance for return on investment (in 1937, $735,000,000) was but 5.9 per cent on the $12,500,000,000 invested in the industry. A further breakdown, not shown in the foregoing table, indicates that payroll comprises 55 per cent of all operating expenses, or 21 per cent of total costs. Another interesting side-light is that in the case of purely hydroelectric power, sold wholesale, 92 per cent of the cost consists of charges relatively fixed in nature (taxes, depreciation and return on capital) and only the small balance of 8 per cent represents operating expenses.

Parenthetically, it may also be noted that, from the investor's point of view, the year 1938 was not quite so happy. Final figures are not yet available, but from the reports that are at hand it seems likely that the proportion of gross receipts available for return on investment will have declined from 36 per cent to 33 percent, while depreciation was about 12 per cent.

It should be pointed out at once that the reason capital costs represent nearly half the total cost is not because the rate of return on investment has been high, but because the relative amount of capital required is so great.

The fact that the annual cost of electric service —particularly of hydroelectric plants—is composed so largely of interest on investment has been largely advertised as a reason for the invasion of the business by public projects. The apparent cost of 3½ per cent to the Government for money is compared

The Egyptian Bow Drill, from a Tomb Painting

with the 7 per cent return necessary to attract—and continue to hold—private capital and to many, therefore, seems to constitute a formidable argument. It usually means, however, merely that the Federal Government is enriching itself at the expense of state and local units.

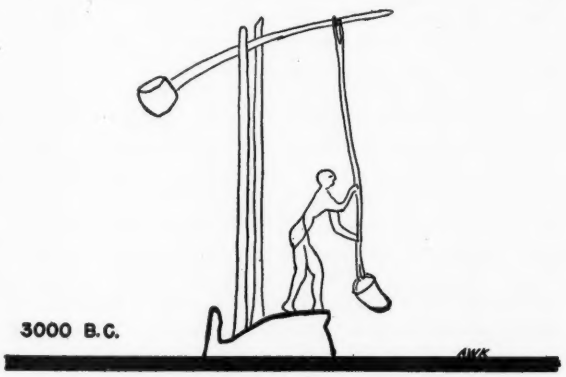
In reality, money costs Government much more and, when all factors are considered, 3½ per cent Government money is actually about the same as the 7 per cent private money required by privately-owned utilities for capital expenditures. The true cost of money to Government is the sum of direct interest plus the results of tax-exemption, because the displacement of tax-paying private property by Government tax-exempts means that this same amount of money must be raised by heavier taxes on somebody else, or else that the government must borrow money to make up the difference.

Let us take as an example an electric property costing $1,000,000 and set up the annual costs in tabular form.

	Private Capital	Government Capital
Return on $1,000,000	$70,000	$35,000
Taxes foregone (16% of annual revenue of 1/7 of a $1,000,000 investment)	——	22,850
Individual income taxes (Federal) lost (say 15% of the $70,000 return on private money)	——	10,500
Individual income taxes (State) lost (in New York State, say 7% of above return)	——	4,900
Total	$70,000	$73,250

A further side-light is also thrown on the questionable benefits, to the nation as a whole, of the Federal Government's policy of excessive development of hydroelectric power.

Although it is well known to most engineers connected with the development of power, it is not generally appreciated by the general public how much in a hydroelectric project of the principal cost of the energy lies in the fixed charges. Less than 10 per cent goes into operating expenses in the form of labor and materials. In a steam-generating plant, on the contrary, fully 50 per cent of the total cost of power goes into continuously recurring expenses for materials, fuel and labor. It has been estimated by Mr. Sporn, Chief Engineer of the American Gas & Electric Company* that for every billion kilowatt-hours generated each year by hydro $2,300,000 less is paid out for labor and materials than if the same production had been made by steam. This amount is obviously reflected in the further reduction of purchasing power and payrolls through the well known downward spiral, so that it is entirely probable that this process results in as much as $10,000,000 to $15,000,000 of annual decrease in the total national payroll for every billion kilowatt-hours of hydroelectric energy so generated. Assuming the maximum possible hydroelectric energy that might be developed by Federal subsidy to be 20,000,000,000 kw-hr. per year, it can be seen that the production of such an amount of energy would mean a reduction



The Egyptian Shaduf

in national annual payroll of between $200,000,000 and $300,000,000. This most certainly is not a negligible item in the national economy.

For the last few months business has largely been stimulated by Federal spending which will reach its peak this coming spring. Unless by that time, investor confidence is thoroughly restored so that private enterprise is able to sustain the momentum, there are few prospects for business improvement to continue beyond the present pump-priming, spending-lending program. Another cycle will take place; industrial production will again decline and legislators will again be under pressure to appropriate huge additional sums of paper money.

When the investor gets discouraged about the future earning power of his money, everybody suffers. For years the greatest source of depression has originated in the so-called "heavy industries"—of which electric power equipment is an important item. Almost without exception, they have lagged, despite the improvement in consumer goods lines in the last 5 yr.

The electric light and power industry used to spend some $750,000,000 every year in building new lines and plants—in 1930 it spent $919,000,000. In 1938 the construction expenditures in this business totalled only $475,000,000, or less than one-half of this amount. Why?

*"Proceedings" of the American Society of Civil Engineers, Oct. 1938, p. 1683.

TABLE I CORPORATE STOCK ISSUES IN THE UNITED STATES (MILLIONS OF DOLLARS)

Year	Public Utilities New Capital	Public Utilities Refunding	All Other Companies New Capital	All Other Companies Refunding
1937	5.8	86.3	397.1	264.2
1936	4.6	43.3	362.9	157.1
1935	1.8	33.0	67.5	48.5
1934	0.6	—	34.0	—
1933	3.3	—	117.1	32.3
1932	6.5	2.3	13.7	1.5
1931	252.9	31.1	58.4	0.8
1930	761.5	13.4	783.6	9.4
1929	1229.1	205.3	4859.6	627.4
1928	757.5	160.5	2313.2	396.0
1927	773.4	68.3	735.8	195.8

Source: "Commercial & Financial Chronicle": stocks include both common and preferred.

The answer lies partly, though not entirely, in the impaired earning power of capital and the changed financial aspects of America. It is a manifestation of forces which, running through all forms of industry in this country, have reached a climax in the electric utilities.

The great mass of investors who, although they individually hold relatively small sums, aggregate a huge amount, were in a 6-yr. protest against the conditions which depressed confidence in industry. And especially, in spite of adequate earnings and a record of continuity of payments on the bonds and preferred stocks of operating companies unequalled in any other line of enterprise in America, nobody wanted utility stocks. It is true that it has been possible in many instances to refinance senior issues, but "junior money", the equity of common stocks so necessary to maintain a correct balance in the capital structure could not be raised.

During the past few years, a large amount of refunding has been done, involving the exchange of high-interest bonds for those with lower coupons. A little refunding of preferred stock has also been done, in which six or seven per cent issues have been superseded by five or five and one-half per cents. None of this, however, helped to encourage new construction or to put anybody back at work.

Where, up to 1931, stocks (and especially common stocks) formed the backbone of new financing, their absence in recent years has been conspicuous. In the utility classification, new capital raised during the whole 6-yr. 1932-1937 inclusive has been 22½ million dollars, or equivalent to the rate for just one week in 1929. During the first 10 months of 1938 new capital raised by utility common stocks totalled only $3,541,425 and no refunding at all was done through stocks.

It is well known that new bonds for additional plant cannot safely be sold, beyond a certain point, without the cushion or protection of additional stock. It is also apparent that the limit of preferred stock has, in many companies, already been reached and that the industry, as a whole, is nearing "saturation" with senior securities. This statement is based upon an interesting comparison between the capitalization of the electric utilities in 1912 and 1922, as reported by the U. S. Bureau of the Census, and in 1937, based on information published in Moody's Manual of Public Utilities.

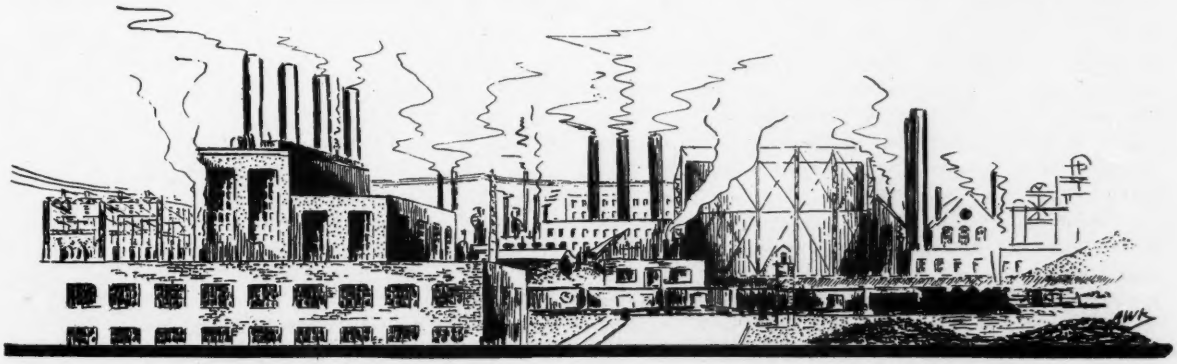
TABLE II PER CENT OF TOTAL CAPITALIZATION

	1937	1922	1912
Bonds	50.4%	51.7%	43.8%
Preferred Stocks	19.4%	11.9%	8.6%
Common Stocks	30.2%	36.4%	47.6%
Total	100.0%	100.0%	100.0%

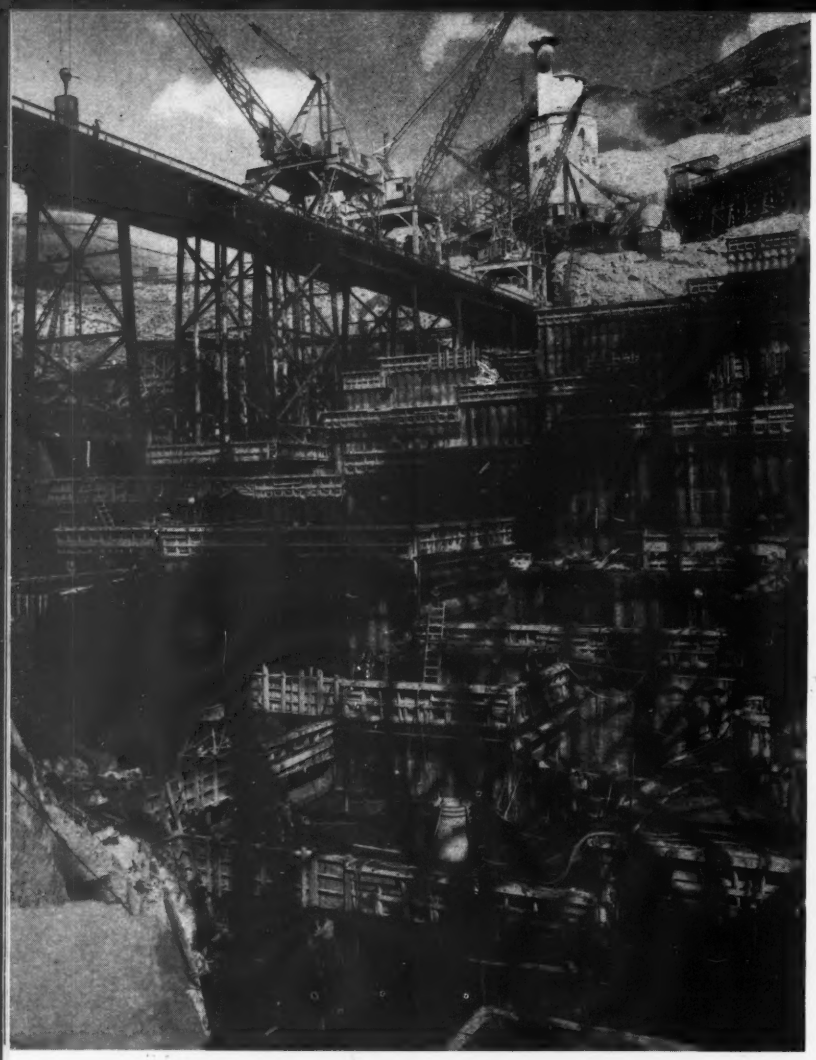
While the proportion of bonds has not changed appreciably, the proportion of preferred stocks is now 63 per cent greater than it was in 1922 and 126 per cent more than it was 25 yr. ago, at the time when the great expansion of electric power was just about to begin. On the other hand, the proportion of common stock—which might be termed "venture capital" and a true measure of the confidence of the investor in the future of any industry—has shown a steady decline.

This more recent deterioration of investor confidence was, broadly speaking, the result of Federal policy. Investors would not put their money into any of the growing number of industries whose direct competitor was the United States Government. It is axiomatic that Federal competition—already potent in electric power, beginning in fertilizers and chemicals, and in sight for food products, tobacco and many other manufacturers—tax free, unhampered by accounting standards and with an unlimited reservoir of funds behind it, can bankrupt any private enterprise.

There is every reason to hope that the recent welcome spirit of cooperation between the utilities and the Government may continue to the point where the market for common stock—the workhorse of the financial world—will again be reopened, so that America will once again proceed up its course of industrial expansion.



POWER



Only the government can undertake to construct such huge projects as those on the Columbia River. A typical construction view at Grand Coulee

TODAY AMERICA delivers an electric power output of 37,032,000 kw., producing 121,050,000,000 kw-hr.; 28.3 per cent of this is furnished by water power. There is still 52,629,000 kw. of potential water power to be built, bringing the total water power of the nation up to 63,000,000 kw.

Taking the 50 yr. from 1887 to 1937 inclusive, the demand rose from 157,000,000 kw-hr. per year to 121,050,000,000 kw-hr., or over seven hundred and seventy-one fold.

Thus the output in the past 50 yr. doubled about every 5 yr. and 3 mo. This term includes the years of the depression.

And what of tomorrow? In about 17 yr. we should have ten times the output. If the depression had not occurred, the last 8 yr. would have been expected to bring an additional 40,000,000 kw., more than doubling the nation's present supply. But this has not been built. It is significant that in the past, every depression has been followed by a corresponding period of prosperity.

Past depressions were not as great as this one. The world was wider. Then came the greater use of telegraph, telephone and radio. Transportation was enormously quickened. Time and space shrunk, and the world was smaller. Great business deals took hours instead of months. Business took on tremendous momentum, with little regulation. And then came the collapse.

But can anyone say that the uprise of business, added to this depression, will not follow the same average as in the past? The shortage of power will be the more acute as the nation's business becomes more rapid.

And where will this power come from? Hydro power will furnish part, but the greater part must come from coal-burning plants. At the same ratio of hydro power to steam power as we have today, America would need 60,000,000 or 70,000,000 tons more of coal a year, assuming that one pound of coal can produce one kilowatt-hour. This points to a number of very large coal-burning plants at the most convenient sources of coal.

Apparently in the coming years, as in the past, history will repeat itself, and we will be like the old lady that kept the boarding house. She prided herself that she could anticipate the exact needs of the boarders, and never had a slice of bread left on the plate. The boarders got exactly enough when the bread was exactly finished. So we will go along like the boarders, getting the bread at high rates, without any regard to appetite, but solely with regard to the barest necessity, and in that way, at the expense of America's development, we will get along with a much smaller electric output.

The New Super Power Age

The percentage of increase of power in America in the past shows us that in only 17 yr. we should be distributing ten times the power used today. Even if this time should be somewhat lengthened, the thought is startling, to say the least. We must soon double the entire output of power of the nation, and in several years add twice as much again, then catch our breath and add four times the present output, and the end is not yet.

It will require huge hydro plants and huge steam plants. Lines that we now build to carry 100,000 kw. must then be built to carry 1,000,000 kw.

Our forefathers went through the Stone age, the

As A National Problem

If the history of the growth of the use of power is any criterion, in 17 years we shall be using ten times the amount of power we are using today. To satisfy this coming need we will need vastly increased plant facilities and greatly extended transmission lines and distribution systems.

BY J. D. ROSS

Bonneville Administrator

Copper age, the Iron age, and we remember the Machine age, with its great engines, belts and pulleys, and then we entered the Electric age. Now we are to enter the giant age of electricity, a Super Power Electric age.

The age of competition is disappearing. Competition still exists among the great majority of our people, but the greatest part of our business is non-competitive. All of our private utilities are monopolies. Price-fixing governs many business dealings. Even labor is now very largely non-competitive, and struggling for complete monopoly. The little fellow has competitors; the big fellow merges with his competitors. Since we are nearly all little fellows, we are the majority of the people, but the minority of the business.

Several millions of our people are out of work. How lovely and convenient it is to put the blame of unemployment on somebody besides ourselves! In Europe they blame their rulers. In America we blame ours. It doesn't matter what form of government or what the political views of a nation, the lily-white mind of the average critic must find a goat somewhere so as to lull his own conscience to rest and reassure himself that it is the other fellow that made all his troubles in the depression. Many of us are blameless, but many bought worthless securities without a proper study of their value, and a few dishonest people capitalized on this weakness.

But whether we are blameless or not in the depression, we cannot expect to rise like a mushroom from so terrible a disaster. We need constructive work, and the production of an abundance of power is absolutely necessary for industry in peace time, and for defense in time of war. Yet when the government builds great hydro plants for us, to help us in the era just ahead, we are prone to give only half-hearted approval, and so build our own barriers between us and success.

Two of the great factors that prolong this depression are the war scare and the putting out of employment millions of people through the use of automatic devices and labor-saving machinery.

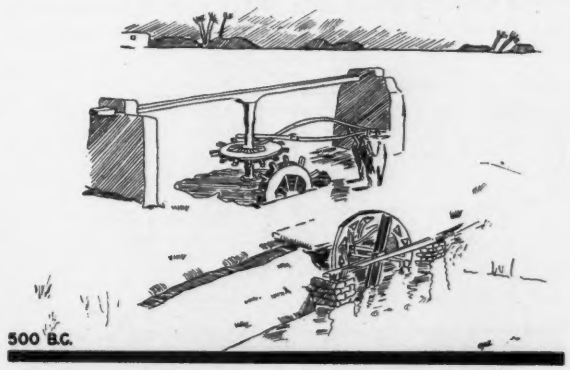
The war scare has lessened, and with the moves for peace in Europe, the increase of prosperity is already noticeable.

"Necessity is the mother of invention." Necessity was never as great as in the last 8 yr., so it brought the greatest train of inventors of all time. As fast as the government cared for the unemployed, more millions were put out of work by new inventions. Much of this invention was in electrical fields, or in devices using electricity. We want all these conveniences to lessen the burden of mankind, but at the same time we have increasing numbers of worthy unemployed that must be recognized and the proper social adjustments must be made.

There are two ways in which these people can be helped, namely: First, by giving all employment possible; and, second, by lessening the cost of the necessities of life. It is here that electric power can play a very important part. The use of power is universal. The light and power bill comes in as sure as taxes. Taxes are secured by property, and can be delayed a year or two, but if power is not paid for, it is discontinued. The rates for power for industry and the farm and home can be reduced by more than half in most cases. "A penny saved is a penny gained," and this saving will offset the equivalent amount of unemployment. Its great use is in stimulating industry and lessening the cost of doing business.

The depression has taught us many a story; some good, some bad.

Among them we have learned that the manipulation and pyramiding of stocks can wreck a nation. But with it we have learned that private power com-



The shaduf was followed by other irrigation schemes in ancient Egypt

panies will not undertake the financing and building of great plants like those of Bonneville, Boulder, Coulee or St. Lawrence. They are too big. We have reached the size where years are required to construct the enormous plants of the future, and further time is needed to load them. Private power concerns undertake their building in times of prosperity, but did not in the past depression while the war scare existed. The only large hydro plant, or plant of any kind, built in the bottom of the depression, 1934 and '35, except federal plants, was the Diablo plant of 130,000 kw. on the Skagit River, part of the million horsepower development of the City of Seattle Municipal System. And the only large power office building was the City Light Building of Seattle.

To the everlasting credit of Wall Street and Chicago financiers, be it said that they furnished the money. The banks were bulging with money, and this illustration is sufficient to prove that no meritorious power plan would go begging for money in the bottom of the depression in 1934. To their further credit be it said that all the bonds used for this plant and office building were Utility Revenue bonds, and therefore the bankers took the risk and looked only to the earnings for their interest and principal.

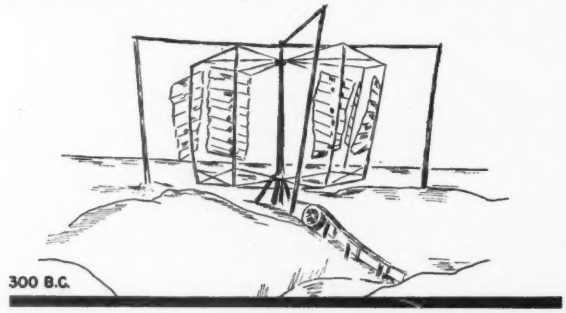
But though Wall Street was ready and willing, perhaps we cannot expect power companies to build so far ahead and on such a grand scale, for they must look for certain profits, but so must the City of Seattle plant, financed in the same way. Public plants, paying taxes—federal and city—are for their people. They are for service, not profit, but somehow, as Ford and Woolworth found, a lower price brings greater volume and greater profits anyway.

The depression has taught us that to prevent disaster from power shortage the Federal Government must build these great plants. Their necessity must be foreseen eight or ten years ahead, whether in prosperity or depression. The production of power must no longer be on a starvation basis, but must anticipate all requirements. Abundance of power stimulates its use to a tremendous degree.

Network of the Columbia River

A federal network of power lines is now being built in the Northwest, and further lines are being planned.

The Bonneville plant is now in operation. The Grand Coulee plant will be in operation in about 4 yr. The Bonneville plant was built and is now operated by the Army Engineers. The Coulee plant is being built by the Reclamation Service. The building and operation of the Northwest Distribution is in charge of the Administrator of the Bonneville Project, also in the Department of the Interior.



Primitive forms of windmills were in use in China centuries before the Christian era

A 220,000-v. tie line 250 mi. long is being built between the Bonneville and Coulee plants as part of the network, thereby welding these plants, as far as distribution is concerned, into a single Columbia System, into which all future Columbia plants will naturally intertie.

The Bonneville plant will deliver about 500,000 kw. of firm power, and about another 100,000 kw. that must be supplemented for short periods. The Coulee plant will deliver 800,000 kw. of firm power, and another 1,180,000 kw. of power that must be supplemented at low water or used for seasonal irrigation and other uses.

The Skagit power plants of the City of Seattle Municipal System will also furnish over 800,000 kw. of firm power, practically all from storage. It is expected that in later years the Skagit system will be intertied, at Seattle, at 220,000 v., with the Bonneville and Coulee systems. The storage of the Skagit system can then firm up much of the seasonal power of the Columbia. This will make a triangle of over 200 mi. per side for the ultimate 220,000-v. tie lines.

The Bonneville Act, authorizing the Administrator to distribute the power of that plant, assumes that the distribution will cover the natural transmission distances, and this is generally thought of as extending over the States of Washington, Oregon and Idaho. The use of direct current transmission where necessary will result in making the distribution distances whatever is desired.

Aside from the 220,000-v. ties and substations, all other lines and substations will operate at 110,000 v.

Current will be sold only at wholesale. The sale price to all customers, large or small, at any point in the three states, will be $17.50 per kilowatt year. This is a rate of about two mills per kw-hr. for 24-hr. load, and higher as the load factor decreases.

The kilowatt-year rate is given to promote the lengthening of the load factor. It will also tend to save the investment in less efficient local plants by using them for peak loads, carrying the long-hour loads on Bonneville power.

As a general rule in handling and selling most commodities wholesale, it costs more to wholesale to a very small customer than it does to very large ones, and prices are usually fixed accordingly. But in the case of a power plant such as the Bonneville plant, the power is all generated in the same machines and transmitted on the same lines, without regard to what customers are to use it, so there is no discrimination between customers. The rate is the same to all power districts, private power companies, municipal plants, co-operatives, and R.E.A.'s. Other plants will be built later at widely different points, and will tie into the network. Therefore the rate is made uniform over the entire area, about 750 mi. east and west. Industry can then locate at the most convenient place. All sections will have equal opportunity in the use of power.

There is one exception, namely, a lower rate for power at the Bonneville Dam for such industries as depend mainly on low rates for electricity for electrochemical work. Since this power is used at the bus bars of the plant, it is not charged the cost of step-up and step-down transformers and transmission lines. The price to all industries at the dam is $14.50 per kilowatt year.

For the Bonneville distribution there is being delivered 5000 tons of copper and aluminum cable, 16,000 tons of angle steel for transmission towers, 271,000 high voltage insulators, together with a large quantity of transformers and substation equipment for various substations. It is expected to finish and put in operation the entire present program in 18 mo., and much of it before that time.

There is plenty of market for Bonneville power. The main object of a public power system is to lighten the burdens and promote the industry of its patrons. To this end all branches of industry will be encouraged; irrigation, mining, wood products such as pulp and paper, rayon and plywood, farming and fertilizers and chemical manufacture. Rates in the home will receive special consideration.

COLUMBIA RIVER POWER FOR ALL THE NATION

The whole nation can have Columbia power in its factories and in its homes.

This statement is past being a prophecy. It is a fact.

This can be accomplished by the use of direct current transmission.

Faraday discovered the principle of the power generator of today. Thomas A. Edison perfected it. It produced alternating electric currents. Alternating current motors were then unknown, so Mr. Edison used a commutator on the shaft of the generator to deliver direct current to the line. The ordinary voltage used in the home did not admit of transmission for more than two or three city blocks, because to transmit farther, a higher voltage or excessively large conductor was needed, since there was no way known to lower the voltage of a direct current at the customer's end of the line. To overcome this difficulty, the transformer was introduced, and we went back to alternating current generators. Time went by, and today the world has billions of dollars in electric systems, alternating generators changing their voltages up and down through transformers, and transmitting 300 or 400 mi. at high voltage.

In attempting to transmit farther than about 300 mi., certain difficulties inherent in alternating current make themselves felt, and materially increase the cost and lessen the reliability of transmission.

The whole trouble arises from the fact that all things possess inertia, and an electric current is no exception. It therefore resists starting and stopping, just as a railway train resists sudden and rapid shunting back and forth. An ordinary 60-cycle alternating current traverses the wire back and forth sixty times each way in the small space of a second. The laws of the alternating current are therefore involved with inertial complications, and the alternating current system's troubles are therefore inherent.

On the other hand, a railway train travelling steadily along its track is not troubled by inertia except when it starts and when it stops. Even then the jar given the train is lessened by starting slowly and stopping slowly. In the same way an electric current, travelling steadily in one direction, is troubled by inertia only on starting and stopping.

Thus, while the laws of alternating current flow are complicated by inductance and capacity, the law of direct current is extremely simple.

The average reader, when he sees a mathematical formula, lays down his newspaper with a sigh. In this case the law of direct current is too simple to be an obstacle. It calls for nothing but the simplest arithmetic. It is the time-worn law of Ohm.

$$I = \frac{R}{E}$$

Where I represents the electric current
E represents the voltage used
And R represents the resistance of the circuit.

In explanation of this law, it may be said that this is the fundamental law that governs every movement of the universe, from the motion of a finger to the motion of the worlds of space. There is no exception.

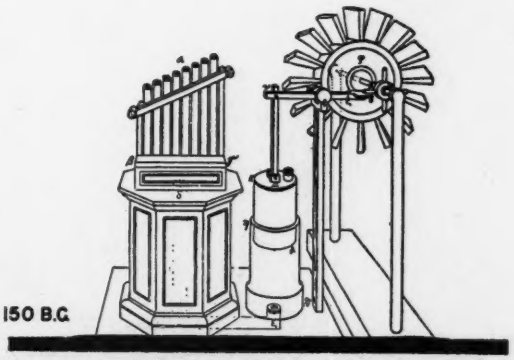
This simple law applied to the transmission of power, i.e., by having the current flowing uniformly in one direction, would solve our transmission troubles and allow us to supply economically millions of kilowatts to Chicago, New York, and all parts of the nation, from the Pacific Coast, with a maximum loss of 10 per cent or less.

All that is necessary in determining the power transmitted is to know the resistance, R, of the wire conductor, and the voltage, E, applied to it. The size of the conductor for any particular line loss is then determined by simple arithmetic.

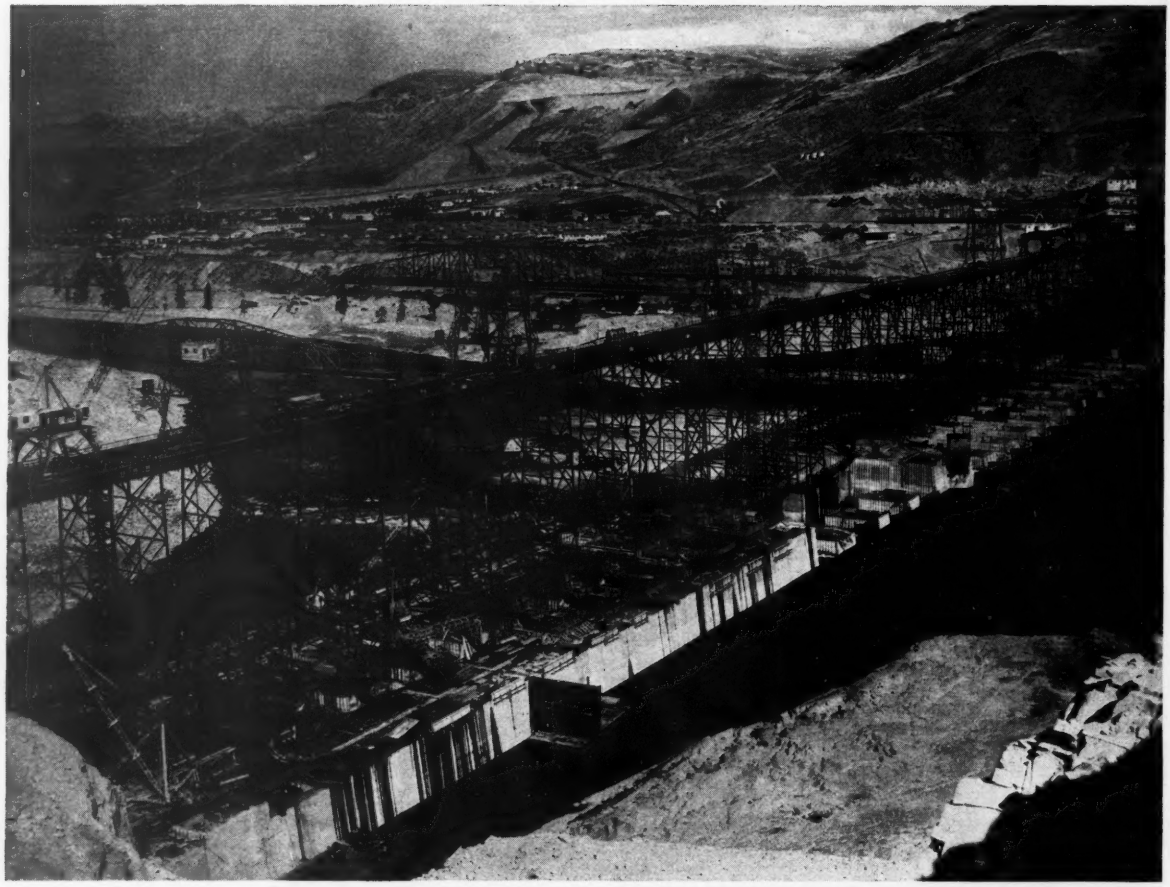
A pair of cables each of 2,500,000 circular mill cross section (about 2 in. diameter), and operated at 500,000 v.d.c., would deliver in Chicago the million kilowatts it uses, if carried from the Columbia River in Washington State, or, if they were operated at 750,000 v., they would carry to New York from the Columbia River the 1,500,000 kw. that New York now uses.

In both these cases there would be a maximum loss of only 10 per cent or less at full load, and lower losses at partial loads.

Chicago and New York of course generate their own power, but the illustration shows how effective a national network of the great government plants could



A windwheel used to drive an organ by Hero of Alexandria



Grand Coulee
Oct. 27, 1935.

We have learned that private power companies will not undertake the financing and building of great plants like those of Bonneville, Boulder, Coulee or St. Lawrence. . . . We cannot expect them to—they are too big. We have reached the size where years are required to construct the enormous plants of the future and further time is needed to load them. . . . The Federal Government must build these great plants. Their necessity must be foreseen eight or ten years ahead whether in prosperity or depression. The production of power must no longer be on a starvation basis but must anticipate all requirements. Abundance of power stimulates usage to a tremendous degree.

J. D. ROSS,
Bonneville Administrator.

Investor confidence is the prerequisite to the continued expansion of every line of industry and it goes without saying that once, for one reason or another, this confidence is impaired then industry—and all who are dependent on it—stagnates. . . . It is axiomatic that Federal competition—already patent in electric power—tax free, unhampered by accounting standards and with an unlimited reservoir of funds behind it, can bankrupt any private enterprise.

C. W. KELLOGG,
President, Edison Electric Institute.

be. There is no home in America that could not be reached from such a national network. As a defense measure it would be invaluable.

Such a government network would make the Bonneville, Coulee, Boulder, T.V.A., and all other large government plants and the proposed St. Lawrence plant, national assets, their value being no longer confined to a local area of 200 or 300 mi. Great coal-burning steam plants could be added where they were needed, for irrigation by pumping.

Such a national network would tend to produce a uniform set of rates for light and power over the whole of the United States. Arid regions and dust bowls could be irrigated and restored in any part of the nation. Manufacture could be placed where other factors made it most convenient. Processing of local products could go on all over the country. The peak load of the day would take 3 hr. to travel across the nation from the Atlantic to the Pacific, and every power plant could help to carry it as it moved the 3000 mi. America is facing a shortage of power. With such a network there could be no local shortages.

Great power plants could be added to the national network regardless of their locality. There is no hydro power site in the nation that could not be connected in as a national plant for all America. Great coal-burning plants could be built in the great lignite fields of Dakota or Texas, or wherever cheap coal can be found. Their market would be all America.

Rectifying Tubes for Direct Current Transmission

Rectifying apparatus is being used on a very large scale to change alternating current to direct current for electrolytic work and for the operation of railways. Many thousands of kilowatts are so used.

The day has already arrived when by putting several rectifiers in series we can raise the transmission voltage to 150,000 v. per wire, or 300,000 v. between two wires, one of them 150,000 v. negative to ground, the other 150,000 v. positive to ground. By grounding the central point of the system at each end, as in the ordinary three-wire system, we have each wire acting as an independent circuit at 150,000 v.

So today it is possible to transmit at this voltage large blocks of power with low losses, over a distance of 600 to 700 mi., or even 1000 mi.

The simplicity of design of the transmission line is very striking. Since only one wire is required for a circuit, it does not require an expensive steel tower, but can be quickly built, using two poles to a tower with a shorter pole across the top. From the middle of this hangs a string of insulators carrying a single cable.

What is needed now is the development of rectifiers of higher voltages, either single or in series, up to 500,000 v. or higher.

There would still be the same alternating current generators, transformers and distributing systems. All that would be necessary would be to cut the transmission line at each end and insert the rectifiers. The transmission cable itself would be the only part of the system carrying direct current.

European concerns claim that underground cables will carry five or six times the voltage, under the steady strain of direct voltage, than they will under alternating voltage. American authorities are more conservative. No doubt higher voltages can be carried on underground cables, and it may be that in many cases direct current transmission could be underground without much greater expense of operation. Cost of construction might be higher, but cost of operation would be lower. The line would be free from storms and lightning.

The rectified current on the transmission line is brought back to alternating current for the step-down transformers, and for distribution, by the same tubes. The grids of the tubes are given an impulse in three tubes in rotation sixty times per second. In this way 60-cycle, 3-phase current is reproduced, or any frequency or phase relation may be had.

National Defense

Since power, and particularly hydro power, is the greatest single factor in national defense, it follows that the building of the great federal plants is one of the greatest defense moves ever made in the history of America.

In peace time these plants produce an abundance of power at lowest rates, and thereby stimulate industry.

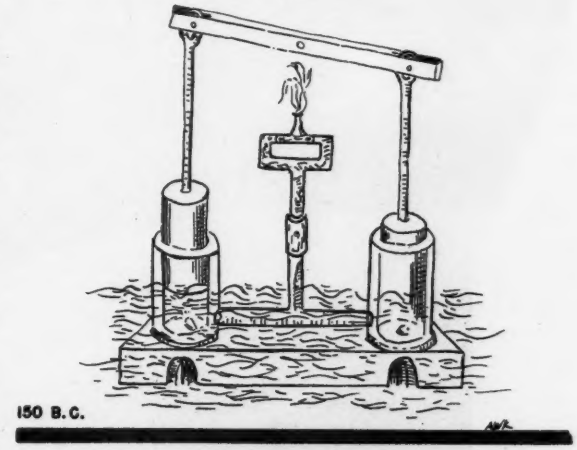
In war time they are the heart's blood of the nation.

Manufacture in war time speeds up at a tremendous rate. Manufacture without power is impossible.

Transportation in war time must also be speeded up to the limit that railroads, ships and motor trucks can be urged. The greater need of fuel for the power plants in every part of the nation follows from the increased need of power. The transportation of these fuels, then, requires a great part of all transportation facilities, and transportation of men and war materials is crippled to that extent.

The great advantage of hydro power in war time is self-evident. The only transportation it requires

Continued on page 68



Our modern pumps seem to be descended from this fire engine designed by Hero of Alexandria

BEHIND IT ALL

The engineers' age old struggle to tap the fuel and power resources of Nature nears success, while a perplexed world, disturbed by the battle but intrigued by the partially harnessed beast, wonders whether to shrink it to fit an overstressed economic system or design a system to fit the Behemoth.

LIES POWER——

BETWEEN various schools of thought seriously interested in solving the economic problems of the world today, there is a wide divergence of opinion. All are agreed, however, that the technical means for producing necessities and luxuries to maintain, or even raise, the present standard of living are available for use, when and if, distribution facilities needed to take full advantage of the potential production capacity are developed.

"Distribution facilities," in an economic sense, refers to the means (barter, theft, charity and money have all been used) by which the consumer gains possession of goods or services and not to the technical means (highways, railroads, commercial and marketing channels) which link the producer to the point of consumption. The problem is, therefore, placed squarely before the economist, sociologist and politician—the group responsible for administering, in the cause of humanity, natural resources made available for use by the engineer.

At present the engineer is far ahead and under this unbalance, our economic system has been sorely stressed. For almost a decade it has not been able to perform its full function which, according to Stuart Chase, is "to provide a means, without excessive waste or loss, whereby those who live under it may . . . (have) . . . food, shelter, clothing and comforts in as dependable and adequate quantities as natural resources and the state of the technical arts permit."

Plans for production based on the technical arts must always preceed plans for distribution so obviously the economist can approach the engineer only after long periods in a static society. This lag is further accentuated by mental, industrial and occupational inertia. The engineer can proceed independently with production but practical progress of the economist is limited by large bodies of people imbued with social, political and business traditions set by a past era and resistant to change. Rapid change always upsets the economic system and causes distress among certain groups or classes.

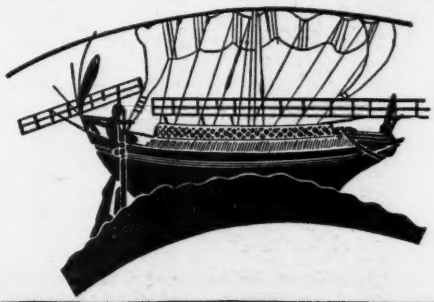
When the comparative stability of the Feudal era was shattered by the Industrial Revolution, handicraft gave way to the machine, lords and nobles to merchants and manufacturers. Manufacturing encouraged the growth of large cities with new problems of transportation, water, sanitation and food services. Invention opened up new industries. Discovery opened up new territory with riches to purchase manufactured products. Labor was a commodity, an integral part of the machine to be held at subsistance level in order to maintain low costs needed for large trade volumes with more backward nations. The base, "those who must live under it" was comparatively narrow and did not include the entire population as it does today, nor, was society as a whole placed above the individual rights of a favored few.

By the turn of the century, world expansion was slowing up, backward countries were beginning to produce more of their own manufactured goods, the rate of population growth was slackening, but productive capacity was increasing. Under these conditions it became evident that the continued prosperity of a country, or group of countries economically related, lay largely within itself, not outside in the accumulated wealth of other and more backward nations. This means that in an industrialized nation, the labor that produces goods must also buy them. Appreciation of this fact is directly back of the current theory of "high wages."

Since the war the problem has been further intensified by two other factors. For the first time since the Industrial Revolution no new major invention is in sight. More may be expected but the fact remains, that, in the past, major inventions have averaged about 225 yr. from inception to commercial importance, so we may expect at least a generation or more with little technical change beyond more effective utilization of what we already have. Again the output per worker has increased so rapidly that the expanding service industries were not able to absorb the excess. Complete failure of the economic system due to this unemployed excess was prevented by emergency means such as relief, public works and in other countries by excessive armaments.

Means for bringing distribution in step with production range from the serious suggestion of temporarily restraining invention and production advances, to a complete revision of the economic system so as to take full advantage of maximum production capacity. Elements of the first method are found in certain of the defunct NRA codes and in the restrictions on labor saving machinery in the present public works program. The second method was used in Russia, Italy and Germany but at a cost few nations are willing to pay.

All this change was brought about by improvements in "the state of the technical arts." The machine started it seriously in the eighteenth century, steam power gave it impetus in the nineteenth century, but it was not until electric power was firmly established in the twentieth century that the machine was elevated from the status of a tool to an instrument of production with man in control and power doing the work. Today power is an entity, largely responsible for economic, social and political unrest, yet amenable to direction which, when fully mastered, will form the key to an undreamed of standard of living.



Greek merchant ship, 6th century, B. C.

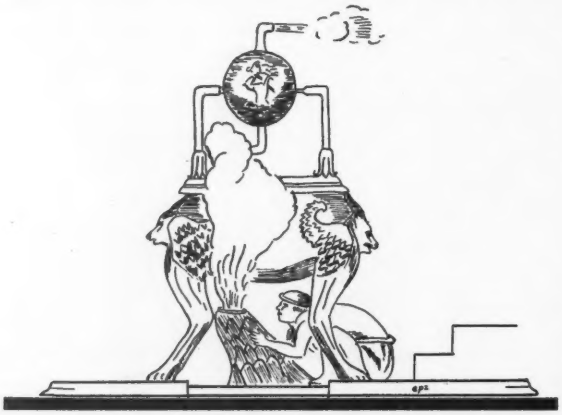
From a fraction of a horsepower in 1790, the prime power availability has increased to a present conservative value of over 10 hp. per capita (equivalent to about 100 slaves). A 50 fold increase has occurred since 1900 following the development of the steam turbine, internal combustion engine and the electrical industry. Manufacturing, however, revolves around stationary power, less than six per cent of the total in which electricity plays the dual role of: A flexible means of power distribution; and an entity in itself which makes possible modern miracles in the scientific, medical, communication, industrial and control fields.

THE MODERN INDUSTRY

SINCE George Washington became president in 1789, the United States has traveled a long and often difficult path, sometimes ahead, sometimes behind, but always parallel with the rest of the civilized world. On this journey the stagecoach, covered wagon, steamboat, railroad and automobile have played a major part and at the rate of progress can be measured in terms of power available for transportation and the allied arts of communication and production.

Washington's inaugural journey from Mount Vernon to New York, at a holiday pace it is true, required 7 da. Today the same 250 mi. can be covered by auto in as many hours or in a few additional hours one can go ten times as far by commercial air lines from New York to Los Angeles, a trip George Washington never dreamed of. A few years before the first inauguration echoes of the shots fired at Lexington and Concord did not reach New York until four days later. Every section of the country and much of the world can now be reached in a few minutes by telephone.

Probably changes in communication facilities have been the most spectacular of all, although rapid progress in all fields followed the discovery and development of electricity. This important step opened up a complete new field and electricity soon became an essential element of power, which may be defined broadly as "the conversion and utilization of energy."



The ancestor of the turbine was this toy described Hero about 120 B.C.

With practically no power, America of 1790 was fundamentally an agricultural community with but 3 per cent of the population living in the six cities of 8000 or over. This was probably not radically different from England, where, in spite of extensive mechanization, but 5 steam engines were being used in 121 textile mills. Water, wind and animal power were feeble, burdensome and fickle, hardly conducive to real industrialization.

By 1850 power was being used to a certain extent but in this country one man was able to distribute the products of four others or 80 per cent of the productively employed population. By 1870 the percentage of those engaged in producing something to eat, wear, sit in, live under, or making tools for this purpose, had decreased to 75. By 1920 it had been further cut to 50 per cent, or, to the point where one man was required to distribute the goods produced by another. The change is not so startling until one realizes that in this short time, three out of every eight productive workers changed over to what is now called the service industries. This shift caused radical changes in the distribution of population and in 150 yr. the 3 per cent of city dwellers increased to about 50. At the same time production increased greatly, although the real increase in output per worker did not come till after the war.

During the latter part of the nineteenth century, manufacturing plants were making considerable use of power and the newly established central station industry was rapidly expanding. In 1899, the available power was about 25,000,000 hp., of which probably half was in animals. This is equal to about 2 manpower or 0.2 hp. per capita. From this point on the pace accelerated. By 1920 primary horsepower had tripled with about 2/3 of the gain in the utility field. Production and the number of persons employed during this 20 yr. more than doubled. Considering the long term shift

in occupations it is not surprising therefore to find that over two census periods people productively employed increased but 13 per cent as compared to a 68 per cent increase in the miscellaneous or service group. This is certainly evidence that in the long run technical developments create new jobs either directly or by exerting economic pressure.

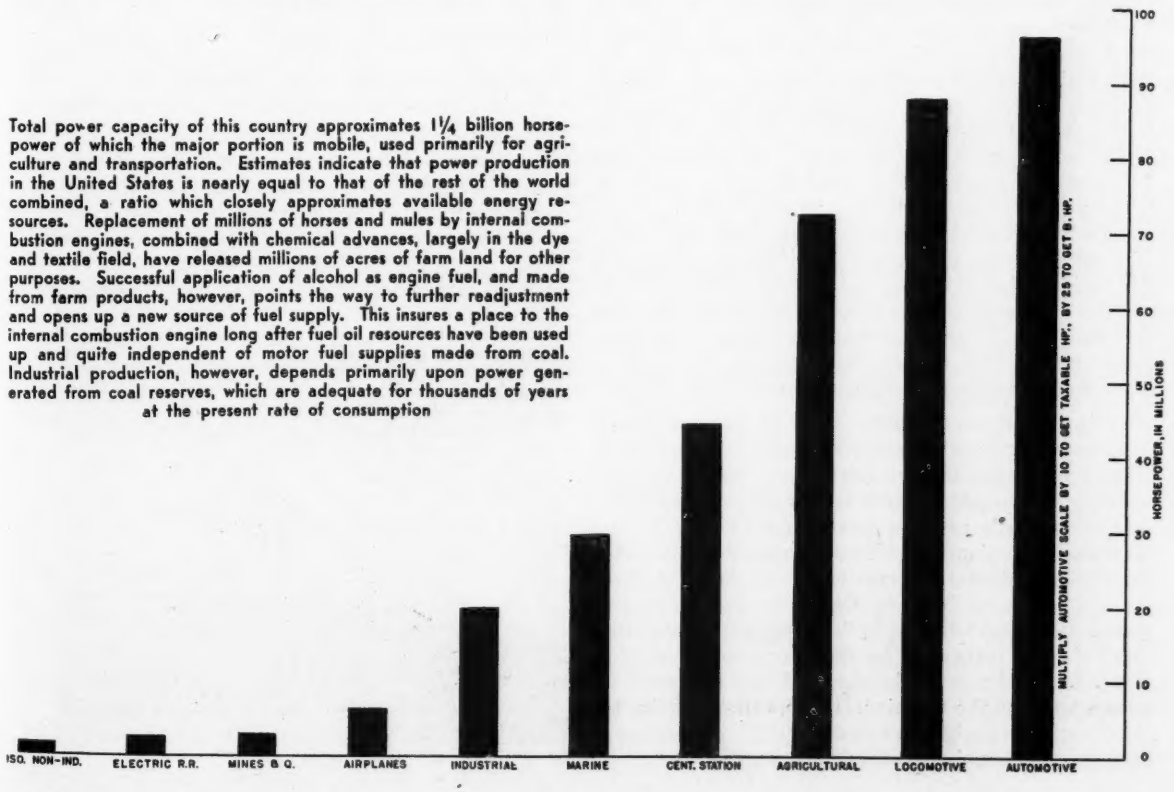
It must not be forgotten, however, that statistics of this kind are extremely unreliable and should be considered only as indicating the most general trends. The census basis from which most of the figures are taken, change from period to period and are not always directly comparable. Furthermore they are incomplete except in a few industries and take no account of part time work, temporary unemployment and shortened hours. Output per worker is almost meaningless, except on a man-hour and standard output basis. This is strikingly shown by railroad statistics from 1899 to 1925. Traffic volume per worker increased by 56 per cent but the increase in traffic units per man-hour was estimated as 100 per cent. Furthermore, recent statistics, vital to current problems are sometimes used incompletely in order to bolster a preconceived opinion. They thus lack the impersonal viewpoint and perspective given by time and necessary for the proper use of data to formulate opinions. Too often the opinion is formed first and supporting data then selected.

There is no question, however, that the nation is learning how to use, more effectively, fuel and power reserves accumulated over many thousands of years and so laboriously developed during the nineteenth century. This trend has been especially marked since 1920. For instance, power used by the average industrial worker in the Detroit area increased from 4000 kw-hr. in 1920, to 8000 in 1929 and 11,000 in 1937. Allowing for the change in working hours, this represents an increase of from 2 to 7 hp. per worker in 17 yr. Detroit, as the center of the highly mechanized automobile industry, stands head and shoulders above the country as a whole. In fact if each of the nation's approximately 20,000,000, employed in production, used the same amount of power, it would require about 150,000,000 hp. or three times the total present central station capacity. What this would mean in increased production is impossible to estimate.

Estimates have been made, however, to show that complete utilization of present technical knowledge could increase production 40 fold, If this were done the 1929 volume of production could be maintained by somewhat over 600,000 employees. Even though this figure be grossly exaggerated it shows the technical strides that have been made of recent years. Furthermore it indicates the tremendous problem involved in incorporating these technical advances and potential benefits in our economic system without wrecking it completely.

Sudden adoption would triple unemployment and probably have a much greater effect on the relief rolls. On the basis of the 1930 census, out of every 10 people only four were gainfully employed, the other six being too young, too old, incapacitated, or not working for some reason. Of these four, at present, one is working for the government, one is engaged in agriculture, one is unemployed, leaving one man, with his time about evenly divided between the basic and service industries needed by the other nine.

In spite of the small proportion of actual workers, the present power capacity, evenly divided, is sufficient



Total power capacity of this country approximates 1¼ billion horsepower of which the major portion is mobile, used primarily for agriculture and transportation. Estimates indicate that power production in the United States is nearly equal to that of the rest of the world combined, a ratio which closely approximates available energy resources. Replacement of millions of horses and mules by internal combustion engines, combined with chemical advances, largely in the dye and textile field, have released millions of acres of farm land for other purposes. Successful application of alcohol as engine fuel, and made from farm products, however, points the way to further readjustment and opens up a new source of fuel supply. This insures a place to the internal combustion engine long after fuel oil resources have been used up and quite independent of motor fuel supplies made from coal. Industrial production, however, depends primarily upon power generated from coal reserves, which are adequate for thousands of years at the present rate of consumption

to allow every man, woman and child from 10 to 25 hp. The discrepancy between these figures lies in the method of rating automotive engines, which form, as shown by the bar chart, by far the largest block of power. On the conservative basis of taxation it amounts to almost one billion horsepower. On the more liberal basis of actual output, however, it might well be increased to nearly 2½ billion, giving a grand total of 2¾ billion instead of 1¼ billion as shown. This country has about half the automobiles of the world, a ratio which holds true not only for the total of all developed power but for the power resources as well. The bulk of these resources lie in coal.

The conservative figure of 10 hp. per capita is the equivalent of about 11 horses or mules, or 100 slaves. The utilization factor is low, however, and is only about 26 per cent for the electric power industry. Even the average Detroit worker who actually uses seven out of his share of 10 hp., does not do as well. Although he uses 11,000 kw-hr., he works only 2000 hr. or less than a quarter of the year.

Although numerically small, the 160,000,000 hp. in the central stations, industrial and railway plants, mines and locomotives, forms the keystone of our economic system. Take away these and the nation would be paralyzed. Food, water and sanitation services would break down immediately. Death and starvation would be rampant and the isolated farmer, independent of mechanical power and with a cellar of food, would soon be overwhelmed by starving hoards fleeing the metropolitan areas.

Of the vital power sources mentioned, the electric generation station group is the only one still growing, the one most involved with future industrial production and the domestic affairs of the people. It is, therefore, the branch which will be studied in great detail. In its broad aspect, this includes both the central stations and industrial power plant which today differ in size and function but are rapidly becoming complimentary, not competitive. From the standpoint of conservation of resources, because of its high efficiency, the function of the industrial plant is to supply power up to the process steam needs. The function of the central station is to absorb the excess, or supply the deficiency, of power to these plants and carry on as a source of supply for domestic, commercial or industrial consumers, not using process steam. The trinity of prime movers, steam, internal combustion engines and water power is thus tied together by the very real network of electric transmission and distribution lines.

The importance of electricity in the present scheme of things cannot be over emphasized. In itself it has made possible the modern miracles of communication, industry and science. As a means of power distribution it has made real the term "labor saving." In a modern power plant, industrial or central station, man supervises and controls; machines do the work from the coal pile to the busbars. Only when something goes wrong does man bend his back or soil his hands. Production is no longer set by the supply of labor, it is determined entirely by the capacity, and the man's intelligent use of the machine. Quite appropriately, the industry that provides the means for full utilization of the machine is the best example of its proper use.

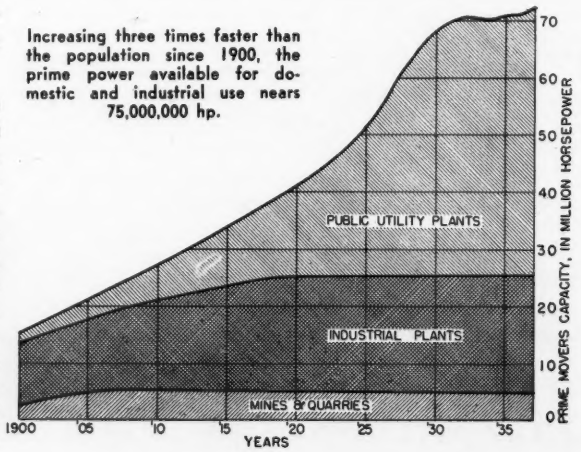
The Modern Industry

The Growth

FROM nothing to a $13,000,000,000 industry employing a quarter of a million people, serving more than 27,000,000 customers and with a gross revenue of over $2,000,000,000 annually, all in the short span of 56 yr., is the enviable record of the electric light and power industry in the United States. At present this represents approximately two-thirds of the total prime power capacity available for domestic and industrial use, but, due to the fact that the remaining third is used primarily for private use on the premises, a direct comparison of the entire supply on the same basis is impossible.

By 1900 power was well established in manufacturing plants, and although it doubled in the ensuing 20 yr., there has been no appreciable increase for the last 20 yr. This statement must not be interpreted as indicating lack of progress in this field. As a matter of fact new capacity, incorporating the same high quality engineering standards as in the utility field, is being added rapidly. The bulk of this is electric power replacing the older mechanical power or obsolete equipment. The net gain in industrial power facilities since 1920 has been largely in electric motors operated by purchased power. This form of power more than doubled in the decade from 1920 to 1930 and is now well over 23,000,000 hp.

The electric power industry, together with its twin, the automotive industry, inherited the hard earned mechanical power experience of the nineteenth century. From struggling tyros in 1900 they grew up together, divided the world between them and methodically set about making it over. That this venture was successful is proven by the fact that almost every fourth person owns an automobile, prac-



tically all urban or metropolitan homes and 20 per cent of the occupied farms have utility electric service and almost a million tractors have displaced 15 times as many mules and horses on the farm. From a peak of 26,436,000 in 1919, horses and mules have dropped to 11,163,000 today with indications that the trend will continue. In 1919 there were less than 100,000 tractors in farm use.

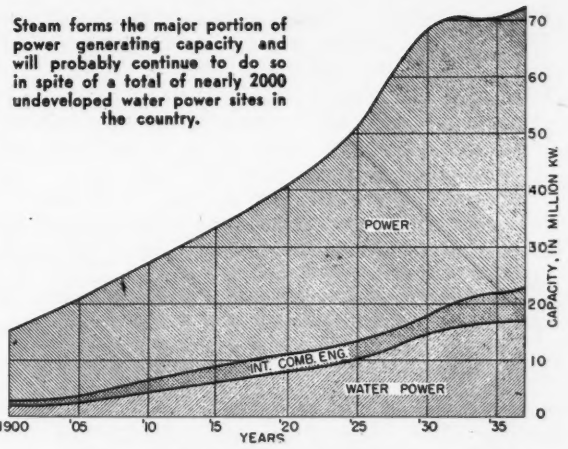
In the decade from 1922 to 1932, utility capacity added at the rate of almost 1,000,000 kw. per year, had almost doubled to a peak of about 34,000,000 kw., about where it remains at present. From 1922 to 1929, generation, increasing at the rate of 7,000,000,000 kw-hr. per yr., more than doubled. During the first part of the depression it decreased at about half this rate, but since 1932 it has been increasing faster than ever.

Further increase of generating facilities is imperative. During 1937 the utility industry added nearly 1,000,000 kw., some of which replaced obsolete equipment so the net increase was about 700,000 kw. Probably as much new construction is under way and this will be further increased by another 1,000,000 kw., expected to be financed through the R. F. C. To this total must be added a hundred or more small municipal plants financed through the PWA and a dozen or more Federal projects which will be completed over a period of years. This activity, combined with a realization of the growing economic importance of electric power, indicates that the industry is just getting a good start and that the expansion period will extend many years in the future.

The Modern Industry

The Plant

PROBABLY the most significant factor in the expansion of the power industry has been the rapid increase in efficiency which has cut the coal rate from over 6.5 lb. per kw-hr. in 1902 to less than 1.5 today. The modern central station can be expected to reach 1 lb. per kw. or better in large sizes or slightly more in small sizes at a heat rate of say 12,000 and 15,000 B.t.u. per lb., respectively. Some of the improvement has been due to improved cycles and the use of higher pressures and temperatures. Some has been due to improved performance of large sized prime movers, electric equipment and auxiliary. A large share, however, has been due to improvements in boilers and fuel firing equipment which has raised the overall boiler efficiency to from 85 to 90 per cent in the better plants.



Steam forms the major portion of power generating capacity and will probably continue to do so in spite of a total of nearly 2000 undeveloped water power sites in the country.

Aside from the large size of individual units, which run up to 200,000 kw., the most striking feature of the present decade is the rapid development of high pressures and temperatures. This phase has been made possible largely through improvements in the treatment of feedwater and metallurgy. Neither of these has reached the stage of perfection, but both have been advanced to the point where pressures up to critical point and temperatures up to 900 deg. F. are commercially practical, and temperatures of 1000—1100 deg. F. are an experimental reality.

The facility with which the industry adopted new equipment and retired the old is shown by figures compiled in 1934 for steam plants of 2500 kw. and over. Out of a total of over 22,000,000 kw., 18.7 per cent was in plants with a heat rate of 14,000 B.t.u. per kw. or under; 38.9 per cent in the range of 14,000 to 18,000; 19.7 per cent, 22,000 to 25,000; 7.1 per cent, 25,000 to 30,000; and 4.7 per cent, over 30,000 B.t.u. per kw. hr. The older plants, however, were used primarily for standby service for 76 per cent of the total out of 43,690,000,000 kw-hr., was from plants of 18,000 B.t.u. or under. The percentage of generation in the six groups of plants listed above were: 28.3; 47.8; 15.0; 4.8; 3.1 and 1.0 per cent respectively.

Inasmuch as a kilowatt-hour is equivalent to 3412 B.t.u., the difference between 30,000 to 14,000 B.t.u. per kw-hr. represents an increase in efficiency of from 11.4 to 24.4 per cent. A rough approximation of the average performance of the larger modern plants is a heat rate of about 12,500 B.t.u. or an efficiency of nearly 27.5 per cent. The world's record for steam plant performance for the year is around 10,860 B.t.u., an efficiency of 31.4 per cent. Industrial plant performance parallels utility plants for the same size range. The boiler efficiencies are directly comparable, but due to the large numbers of industrial plants that use extraction or back pressure steam for process use, no conclusions regarding efficiency of power generation can be made. With complete utilization of exhaust steam, the power generation heat rate approaches a value of 4000 B.t.u. per kw. for all size plants.

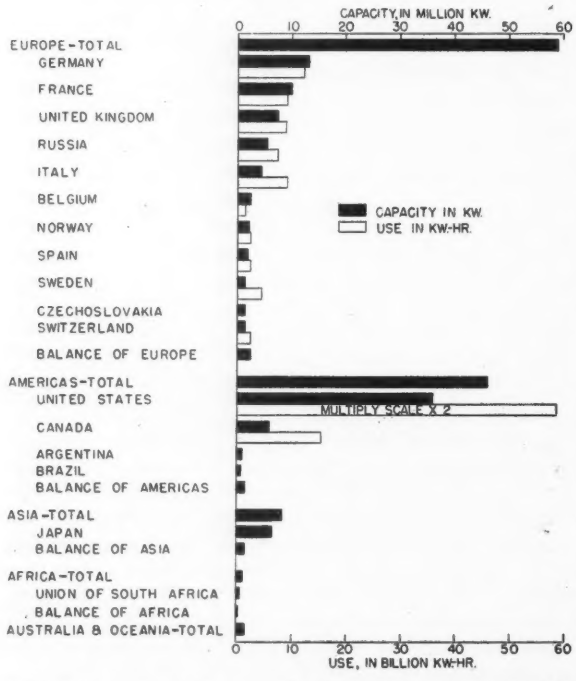
The small steam plant, concerned only with power generation, is under a decided handicap from the standpoint of fuel efficiency. Fortunately, however, the Diesel engine fills in this gap very nicely. A sharp

demarcation between the economic steam and Diesel field cannot be drawn. It probably lies between 1000 and 2000 kw., although a number of larger Diesel plants are operating in widely scattered parts of the country. Utilities make extensive use of the Diesel, but its greatest field seems to lie in the industrial plants and in the smaller municipalities.

Larger engine sizes tend to be more efficient, but the size factor is not as important as in steam plants and the performance varies between about 10 and 12 kw. per gallon. The lower figure corresponds to a thermal efficiency of about 27.5 per cent, or about the same level as a modern large steam plant, while the higher figure corresponds to about 33 per cent or considerably above the most efficient steam plant. Efficiency curves of both types of plants have been flattening out of recent years and are approaching a probable limit of about 34 per cent thermal efficiency corresponding to a heat rate of approximately 10,000 B.t.u. per kw. Some further increases may be expected from mercury vapor and perhaps chemical cycle plants, when justified by fuel prices and load conditions.

Then there is the ever present possibility that some sort of primary cell or battery, to convert coal direct to electricity, will be made commercially successful and enable the fuel plant efficiency to approach that of the hydraulic turbine. Development work on this oldest form of mechanical power has not lagged and the overall efficiency approximates 90 per cent as an upper limit. Heads of from a few feet to many hundreds of feet are utilized in turbine sizes up to 115,000 hp. Increase in water power capacity has not been phenomenal, but it has been steady, the public utility capacity alone approximating 10,000,000 kw.

A most ambitious program of water power development has been undertaken by the Federal government. Ten projects, in which the government is directly or indirectly interested, have a total ultimate capacity of some 5,000,000 kw. All of these are under construction, but only a fraction of the capacity has been completed or contracted for. These plants use the conventional reaction (Francis type), propeller and movable vane runners. Development of the last two types since the war has been done much to further the utilization of low head sites.



Distribution of public utility capacity of the world with an indication of the total electric power generated in countries where the data are available. Only plants generating power for resale are included as no world data are available for industrial plants generating power used on the premises. The total is somewhat over 110 million kw. or roughly 150 million hp.

The Modern Industry

The Distribution

UNFORTUNATELY, statistics on the distribution of power generating facilities throughout the world are entirely lacking or so incomplete that a comprehensive picture cannot be drawn. For this reason it is necessary to rely almost entirely on that branch of the industry that generates power for use or sale outside the premises. Unsatisfactory as this may be, it does show the preponderance of power facilities in the United States and the more effective utilization. Germany, the nearest single country with a population roughly half that of the United States has about one third the capacity and generates about one tenth as much power.

In 1937, however, somewhat less than 20 billion kw-hr. was sold in this country for domestic and farm use. This is only about 150 kw-hr. per year per capita or about 830 per customer, a figure which is exceeded by a number of foreign countries. The only conclusion available is that a larger proportion of the total foreign power capacities is in industrial plants equipped to take care of their own needs. In this country approximately half of the industrial load is carried by motors supplied with purchased power and commercial loads account for more than 70 per cent of total electricity sales.

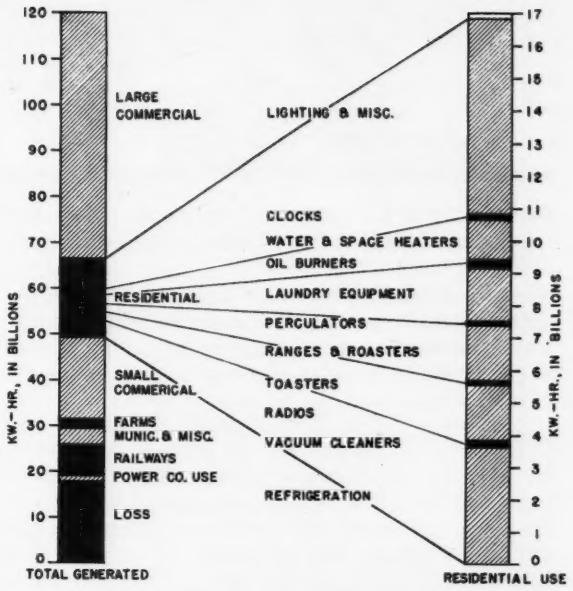
From a purely technical standpoint, Europe has, if anything, led the United States up to within the last year or two. Following theory more closely they investigated and applied, experimentally at least, high pressures, high temperatures and unconventional boiler designs, up to and even exceeding the limits of materials available at the time. In the face of rapid expansion, the United States followed a more conventional course based on past experience and has always led in commercial application and operating technique. The present high temperature, high pressure era puts the two continents practically on a par as far as cycle limits are

concerned and still leaves the United States in the lead in operating technique, size of stations and utilization.

The accompanying chart, made up from data on 97 countries, shows the total electric utility capacity of the world to be over 110,000,000 kw. This is divided roughly as follows: North and South America, 42.2 per cent; Europe, 53.7 per cent; Asia, 1.6 per cent: Africa, 1.0 per cent; Australia and Oceania, 1.5 per cent.

Utilization of energy resources is low, probably less than 10 per cent, for the industrial world. World Power Conference estimates for 1925 based on then available data placed the annual energy production of the world as equivalent to about 1590 million tons of coal. This was divided as follows: Europe, 40.9 per cent; America, 50.4 per cent; Asia, 6.4 per cent; Australia, 1.2 per cent; Africa, 1.1 per cent. Estimated energy resources of the world, coal, water power and petroleum products were divided about as follows: America, 61 per cent; Europe, 13.8 per cent; Asia, 21.6 per cent; Africa, 1.0 per cent; Australia, 2.6 per cent. Europe is, on this basis, making the most effective use of its resources, but even though it produces 40.9 per cent of the world energy with but 13.8 per cent of the total resources, the supply will last over 1300 yr. at the present rate of use.

These estimates, which must of course be considered as nothing more than intelligent guesses by experts in the field, are sufficient to show why America leads the world in the use of power. It also points to the probable direction of further development. Obviously, Africa with an extremely limited supply of energy resource can hardly look forward to a commanding industrial position until some simple means of releasing atomic energy is discovered, or, until the sun's energy can be utilized directly in connection with long distance transmission. Russia too has been looking to the sun as a possible source of power for the desert regions of Asia. The energy resources considered above do not, however, consider the vast quantity of energy available in the sun's rays, tide, wave or power from small temperature differences in the oceans, all of which have been utilized experimentally.



Division of the power generated in the United States, between various classes of users and a subdivision of domestic power. In 1937 the domestic consumption amounted to 793 kw-hr. per customer, an increase of 9.1 per cent over the preceding year. The average domestic revenue was 4.39 ct. per kw-hr. and the average annual bill was $34.81. Commercial service, both large and small, averaged 17,281 kw-hr. per customer at an average revenue of 1.72 ct. to give an annual bill of $282.

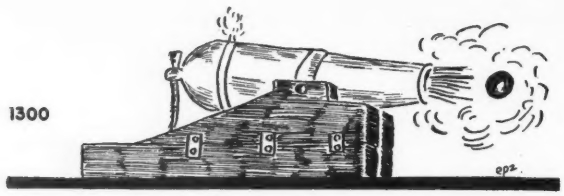
The Modern Industry

The Use

GENERATING FACILITIES are, of course, important but the utilization of these facilities is the measure of their influence on the life and habits of the people. The automobile, creating a new industry in itself and demanding a score of supplementary industries and a network of hard surface highways, provides a flexible, convenient and universal transport media which has done much to promote national unity and tolerance at the same time intensifying the American tradition of individual independence. Quite aside from the financial embarrassment of the railroad and traction industry, the cost of the automobile has been, and is, high, over 100,000 lives each year. This is equivalent to wiping a city such as Duluth, Minn., or Waterbury, Conn., off the map each year, a price that rivals the World War, makes the French revolution pale into insignificance and the current German anti-Semetic campaign read like a minor traffic accident.

In related fields the mobile internal combustion engine has made impressive gains. In agriculture, 1,000,000 tractors have in the last 20 yr. displaced 15,000,000 mules, and shifted perhaps half the burden of fuel supply from the farm itself to the oil fields. Diesel tractors alone are adding more than 1,000,000 hp. per year to our total power supply. Diesel locomotives will soon be doing as much, while giving a bizarre streamlined and youthful touch to an ancient industry that once remade and ruled the nation after fighting, a century ago, for existence against the stage coach and canal. A hundred years ago railroads were fought with expert opinion that the frightful speed of 15 mi. per hr. would cause blood to pour from the noses, ears and mouths of passengers. Today the railroads fight uncontrolled competition with the threat that financial collapse of the industry will carry with it insurance companies, banks and the entire financial structure of the country. No longer does one industry stand alone, competitors and complements, all are tied together in the complex web of our modern economic system woven by power.

As a horizontal industry serving all others, it is impossible to measure the effect of the electrical industry on the country except in most general terms of a total industrial index as will be done in later articles, and, by the development of new industries made possible by invention and development. The movies, radio and electro-chemistry all three commercially developed



Although the Chinese and the Arabs knew gunpowder, it met its first practical use in Europe

within the present generation, exist only through electricity. Faraday, genius that he was, could not have realized the measure of truth in his remark to the skeptical Gladstone that his new toy would someday be good for taxation.

The electrical utility industry alone pays some $330,000,000 annually, over 16 per cent of its gross revenue, in direct taxation. In spite of the rapidly increasing importance of this item, doubled since 1922, the cost per kilowatt hour has been steadily declining. Residential service has decreased to 50 per cent of the 1913 cost while the cost of living has risen 50 per cent. In 1937, due largely to increased use, cost of power for all services was greatly reduced and averaged 2.19 ct. per kw-hr. for all classes of customers. The largest block, as shown by the chart, was commercial light and power (large and small) which averaged 1.72 ct.; the next was the residential block averaging 4.39 ct. In the east where little or no irrigation is involved, rural power averaged 4.72 ct. while in the west where the average use per customer was five times as high, the average was only 1.80 ct. per kw-hr.

Unfortunately, it is not possible to segregate the power used in industry. The large and small commercial customers, only about 15 per cent of the total, used about 72 per cent of the power. Approximately 260,000 of the large commercial customers used roughly 53,500.000,000 kw-hr. If we assume that this is largely used for power purposes, we have a basis for estimating the total power used in the country including that generated in private industrial plants.

Roughly, ½ of the industrial power capacity is in the form of motors operated by purchased power, while the remaining ½ is in the form of prime movers. With the same utilization, this latter half would develop about 50,000,000,000 kw-hr. annually. This gives a total power use of about 150,000,000,000 kw-hr. annually or around 1200 kw-hr. per capital per year.

The estimate is conservative, for the lighting involved in the large commercial customer consumption is probably more than balanced by power used by the small commercial customer and no allowance has been made for the fact that the private plant is used up to the limit of capacity in order to reduce the purchased power bill. Neither does the estimate consider approximately 5,000,000 hp. of known capacity in mines and quarries and unknown capacity in service plants.

The discrepancy between the "generated" and "used" figures quoted above is due largely to losses and utility company use. The utility industry, in 1937, the last year available, reported a generation of 115,165,636,000 kw-hr. which was increased by purchases to a total input of 119,810,348,000. Of this, 99,446,364,000 kw-hr. was sold to ultimate consumers, the balance being used for electric railways, other company departments or was unaccounted for. Of the total generated, 74,206,276,000 kw-hr. was from fuel plants and 40,959,360,000 kw-hr. from water power. The total capacity of 34,960,321 kw-hr. was made up of: 24,637,926 kw. in steam; 9,634,041 kw. in hydro; and 688,381 kw. in internal combustion engines. No separation was made in power generated by steam and engines but from past years and the rate of increase since 1934 it can be placed as slightly more than 1,000,000,000 kw-hr. or almost as much as the 1,215,711,000 purchased from over the international borders.

The year 1937 showed over 1936, a gain of 3.5 per cent in the number of customers; 10.4 per cent in consumption, and 6.7 per cent in revenue, the only loss being 32 railroad customers which had no material effect on the whole. Indications are that the production and use of power will continue to increase over a long period of time but the immediate future of the utility industry is somewhat obscured by differences with the government over an unstated, and probably undetermined power policy, and, the fact that large blocks of Federal hydro power now under development will have to be absorbed.

The Modern Industry

The By-Product

POWER ITSELF has been the major factor in shaping our modern civilization and for the last 30 yr. electricity has been the dominating influence in utilization. Electricity also plays another role in which power utilization is incidental to the practical application of electrical phenomenon. Thus modern forms of communication such as the telegraph, telephone and radio are made possible by the phenomenon of magnetization and ionization, which no amount of mechanical power could replace.

Fifteen of the modern manufacturing industries, commercially developed since the invention of the incandescent lamp, have created directly or indirectly 15,000,000 new jobs, and depend in some degree on electricity. Some of these, such as petroleum refining and rayon, use electricity as a convenient source of power which if necessary could be furnished mechanically. Others, such as electrochemistry, depend entirely upon large quantities of cheap electric power. Still others, like the internal combustion engine and the movies, use comparatively small quantities of electric power as such, but its absence would have necessitated a radically different development.

Without electricity for ignition of gasoline engines, the automobile industry would of necessity had

to depend on steam or have waited on the accelerated development of the small high speed Diesel. It is not generally known that the steam truck was well started in England early in the nineteenth century, but was legislated out of existance under the skillful direction of the stagecoach and newly started railroad interests. A hundred years later it staged a comeback, but was again beaten by the gasoline automobile. The aeroplane is another branch dependent upon electricity. Steam might serve as motive power, but only electricity can supply the flying aids that commercial aviation depend upon.

The motion picture industry, too, which likes to look upon itself as a $2,000,000,000 industry, owes its size to electricity. Gas lights and the phonograph record would make even talkies possible, but it is the concentrated filament of the electric lamp, electronic amplifiers and electric transcription that makes present standards practical. It is generally conceded that under this stimulus even the technique of acting, directing and producing has improved, thus effectively demonstrating that the actual consumption of power on a kilowatt basis is no true measure of its influence in the life and action of the times.

This industry, like others, has of course borrowed freely from the radio industry which did not get a real start until after the introduction of electronic tubes. Excepting the introduction of moveable type which acted only to broaden the scope of communication facilities, no real innovations in speed were added between the domestication of the horse and the introduction of the telegraph. This was closely followed by the introduction of the telephone, wireless, radio broadcasting, facsimile reproduction, the teletype and television; all of which combine to bring the far corners of the earth within a few seconds of each other. Due to the slowness of communication the Battle of New Orleans was fought after the peace pact was signed. The recent Czechoslovakian crisis was followed simultaneously by the entire world.

Closely allied to these, technically at least, are the X-ray, ultra high speed photography, the neon lamp and modern instrument control. Gamma rays from radium can be used, but the flexibility and versatility of modern radiography depends on the high voltage X-ray tube. Important as this is to industry, there can be no question but that its widespread use by the medical and dental professions is of more real value to humanity. Medical science has made extensive use of electricity in many forms, the most spectacular perhaps, aside from the X-ray, being: the electric cardiograph used for studying the heart action; the electric knife useful in certain types of surgery; ultra violet and infra red rays for skin diseases, sterilization, vitamin deficiencies and localized heat treatments; and short wave therapy, utilizing the principle of induction heating in localized areas of the body and the generation of artificial fever.

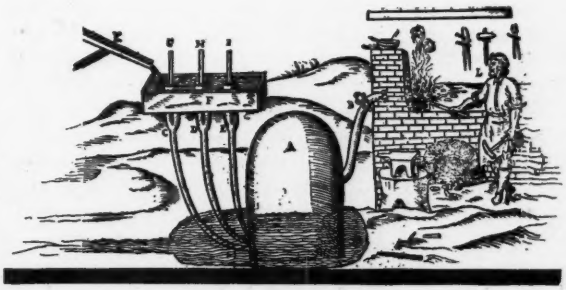
Electric sparks giving a high intensity light of short duration made practical high speed photography and provides a mean of studying actions that take place thousands of times faster than the eye can see. Practical use of the ionization of gases and certain vapors has been used for years in the mercury vapor lamp and its recent application to other gases has of recent years revolutionized the electric sign industry. Recent development of the secondary emission lamp promises to create as complete a revolution in the general lighting field.

Welding, metallurgy and general industrial research, which makes modern power generation possible, depend largely on electricity, either directly or indirectly through its use in heating, instruments or control. The pyrometer and light sensitive cell have accomplished miracles. Research, which has developed into an industry of its own, represents an annual expenditure of a quarter of a billion dollars by industry alone. Much of this is carried on directly in the electrical industry, but in all of it electricity plays the role of an important tool.

To the general public, however, the more prosaic uses of electricity identified directly with their life from day to day, are the most important. There is some question whether these uses can be considered as byproducts of power. The electric industry, as represented by the public utilities, started as an improved method of private or public lighting. It continued as such for many years and it was not until the motor was developed that electricity began to take a dominating position in industrial production.

Lighting continues to be the universal application and accounts for about 28 per cent of the total power used in the home. A recent tabulation, which may not be complete, does, however, list some 196 uses for electricity in the home. Due to an active advertising campaign over a period of years electric refrigerators have shown an impressive gain during the depression. The power they use is already about 60 per cent of that used for lighting and it is estimated that the saturation is only about 50 per cent.

Radios, clocks, flatirons, washing machines, vacuum cleaners and ironers, have an established place in our present standard of living, but ranges, water heaters, oil burners and space heaters meet severe competition from the gas and coal industries and the saturation will unquestionably remain low. Air conditioning in the home offers tremendous possibilities, doubly attractive because the power consumption would fit nicely into the summer low load period. Commercial air conditioning has already shown quite phenomenal increases in certain metropolitan districts, but the domestic air conditioning load still lies in the future.



Brancas design for compressed air blower for a forge about 1500

POWER As A Problem

Where shall we look for future sources of heat and power in the face of a gradually dwindling supply of fuel? Alcohol made from farm products looks promising, direct use of energy from the sun gives promise but fuel reserves are sufficient for centuries and effective utilization of power is a more pressing problem.

SINCE FUEL can be burned only once, a fresh supply must continuously be available if our highly productive type of civilization is to proceed along its charted course. The trend of its curve is strongly upward. As time passes, as population increases, more power and heat are consumed per capita. More than any other single gauge that can be applied by statisticians, the unit of energy, the kilowatt-hour per person stands supreme as a measure of the abundance of living, and the production of wealth.

In the short period of 60 yr., our factory horsepower has increased five times as fast as the increase in our population, and the total available horsepower per capita has reached the astonishing total of ten. This same short period likewise witnessed a multiplication and distribution among the majority of the people of goods, equipments, comforts and luxuries the like of which could not previously have been conceived by the mind of man.

The number of jobs provided by industry by virtue of the application of power to production has increased much faster than population while the average wage earner's income has been multiplied by four. Surely these are blessings which should be expanded and extended until, while we may still have some poor with us, their number will be a very small minimum.

Water Power

Where then shall we look for future sources of heat and power in the face of a gradually dwindling supply of fuel?

Energy, and we think of it today in its convenient electrical form, is derived chiefly from fuels, and fuels are required for heating and processes as well. For example, in this country, over 90 per cent of the total power consumed is produced from the heat energy of fuels, and 60 per cent of this from the combustion of coal. Most of the balance of 30 per cent is derived from the combustion of oil, gas and other fuels.

While these proportions vary widely in different countries of the world, they apply to the greatest industrial country of all, and may perhaps be considered not too far away from a median condition for the industrial world as a whole, considering weighted demands and sources. If all the water powers of the United States were developed, the energy so generated would be equal to about half of the energy that could be developed by our present annual coal production if burned in modern plants. This estimate favors water power inasmuch as it would not be economically practicable to develop many of the included water power sites either now or in the far distant future.

It is therefore evident that natural water powers cannot be depended upon for future supplies of energy to any great extent. Improvement in the efficiency of fuel applications will of course have some effect in postponing the evil day of shortage, but that effect is very much limited by the progress already made or under way. Steam can be generated at a thermal efficiency of about 90 per cent, and even higher if, and when, it may pay to spend the money for extended heat reclaiming.

Carbo-electric plants can now deliver a kilowatt-hour for 10,600 B.t.u. representing an over all thermal efficiency of 32 per cent, and this approaches the possible limit of our known steam cycles even with such higher temperatures as newer metals development may allow us to employ. The efficiency of conversion of electrical energy into light is still very low. With the advance of knowledge in chemistry and physics it is a fair prediction that radical improvement will be attained in this field.

In electrical transmission and transformers, improved methods and efficiencies are already indicated for the future. Motors have already touched efficiencies so high as to leave but slight improvement over their performances for future designers. All of the gains from electrical efficiency improvements are only of such order however as soon to be counteracted by the increased demand for more power.

The Diesel

While the Diesel has under test given about 40 per cent efficiency, yet in actual practice based on station out-put over long periods, it has not attained to the best steam plant efficiency and but little more can be expected. Internal combustion engines in general can be somewhat improved as to efficiency though the conditions imposed in the automotive field present diffi-

In Energy Conversion

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culties and restrictions. Two-thirds of the horsepower in the U. S. is in the form of internal combustion engines, automotive power included.

In the industrial plant where power and heat are both required, where exhaust can replace direct steam, the large condenser loss of the central station may be eliminated, showing a possible over all thermal efficiency of perhaps 80 per cent. The number and size of such future opportunities are limited.

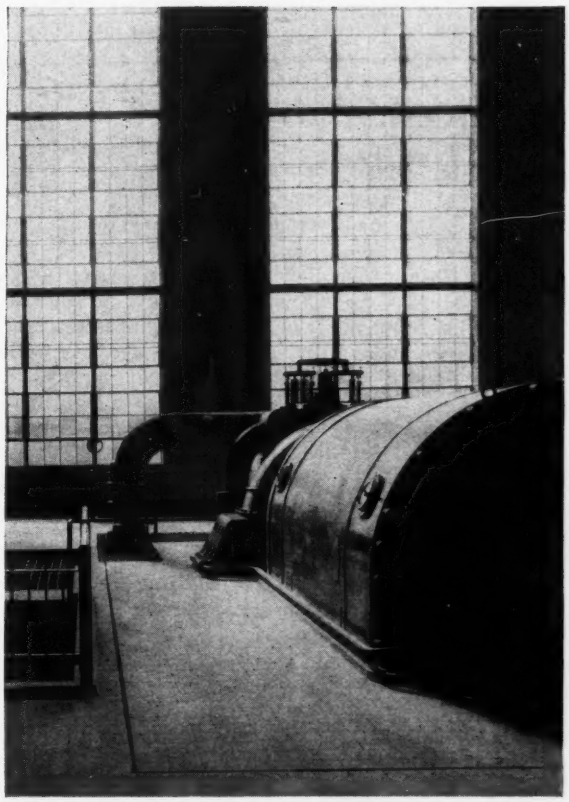
Binary vapor power systems offer somewhat better efficiency than the straight steam condensing system, but from present knowledge and practice do not hold out great encouragement. Direct applications of fuel to industrial processes in the metallurgical and other fields have already been vastly improved, as for instance, in the virtual elimination of the old wasteful bee hive ovens in favor of the by-product system of coke production. Only a slight future fuel saving in this field can be looked for when regarded with respect to the fuel situation as a whole.

From the foregoing it is evident that while improvements in the efficiency of our known and practiced methods of energy production and heat utilization are valuable and amply worth the vast effort and research they entail, yet never can they do more than slightly defer the fateful day of fuel shortage. Also, it is true that the natural water powers of the world can do no more than help a little in the economy of the situation.

The world supply of coal was estimated at the International Geological Congress (1913) at 7,397,553 million metric tons more or less readily minable. More than half of this supply was in the United States. There are undoubtedly unsurveyed fields which may add perhaps a large but unknown quantity to this reserve.

Coal and Oil

While our own supply of anthracite coal is approaching a known end, the substitutions of other fuels has extended its life to somewhere between 60 and 100 yr. at present rate of consumption. Bituminous coal on the other hand should last 1000 to 2000 yr. in this country and probably throughout the world. As it becomes more valuable, better and less wasteful mining methods will be employed which will extend its life and usefulness. If fuel costs enough the last word in conservation and efficiency will be applied.



Natural oil resources at the time of the great war were estimated according to the best geological surveys to have a life of perhaps 20 yr. Today, with the discovery of new fields and the improved working of old fields, the supply is believed to be sufficient for a period of 50 to 100 yr. Modern improvements in producing gasoline from natural gas have extended the supply of petroleum products materially. Sixty per cent of the world's out-put of natural oil and gas is produced in the United States and the equivalent of this amount is consumed here.

When the supply is exhausted it will be possible to turn to vast reserves of oil in shales and tar sands on this continent estimated to be sufficient for hundreds of years. All this awaits the time when the mining of this fuel becomes economically desirable. Liquid fuels can be made by hydrogenation of coal as practiced to some extent in Europe, but this has no effect toward extending total resources.

Wood as a power fuel has its limited application, as for instance in certain large timbered districts where in ground form known as "hog feed" waste is sold to power plants. But wood is too valuable for other purposes and too limited in supply to be considered a competitor of coal or oil. Our country has 10 per cent of the world's forests and consumes 40 per cent of the

annual cut. Unless scientific reforestation is soon extended and practiced, the supply of wood will be gone long before we have to worry seriously about our legitimate fuel reserves.

Peat as a fuel might be mentioned but has practically no significance for power or industrial consumption due to its limited supply in shallow beds and its low grade character.

Conservation and Economy

Various plans relating to conservation, processing and transportation of coal have been the subject of extensive research and experimentation and considerable practice. For instance, we have heard much from the advocates of "mouth of mine power plants" and we have such plants in operation. These plants do not save coal so perhaps should not be brought in here. The principal saving when they are properly located is in the elimination of freight charges for transporting coal to the boilers. But if the mine-mouth plant is not near enough to its market for selling its power, and if it does not have a good and ample water supply, its greater transmission costs and its poorer vacuum will prove more of a handicap than the advantage of saving freight, and dollars will be lost.

It would require one of the largest mines to supply what we would today call a fair size of modern power station. A single mine to a single plant may not provide as steady a supply as when the coal comes from several mines. The cost of transmitting electric current may run 1½ mills per kw-hr. for 100 mi. to 3 mills for 300 mi. It may often be found cheaper to transport coal 100 mi. than its equivalent electric energy when all the factors of a given case are considered.

There has been seriously proposed a plan of gasification at the mines, the idea being to set fire to the coal, seal the mine, pump in air and draw off carbon monoxide for use in gas engines. Let us pass on quickly to the next. Pumping coal from the mine to the market is interesting and careful surveys have indicated its practicability with a considerable saving in cost of transportation in cases where good load factor and other conditions are favorable. Primarily however it is not a coal saving plan.

Low temperature carbonization has for its object the conservation of the very valuable by-products of coal now wasted in the process of combustion. There would result smokeless carbonized house fuel in briquette form, rich fuel gas, ammonia and cyanide compounds to furnish extensive fertilizer demands, light oils and benzol as substitute for gasoline, creosote as wood preservative, and a long and varied list of derivatives including aniline dyes and medicines. Gradually more extensive operations in this field may be looked for in future developments as the market expands in its demand for the by-products. At the present time this market is insufficient to warrant a scale of production in this country such as is already practiced in Europe. The art only awaits its economic demand, but it will not extend the supply of coal.

Iron was made in hillside bloomeries until around the 15th century

So far we have reviewed the usual sources of heat and power. We have found their supplies not inexhaustible and that improvement in the efficiency of their use and application can have only a small effect in extending the time of their depletion. Let us now look into the more unusual sources starting for example with the radiant heat of the sun.

The Sun and Tides

Scientists have estimated the heat given off by the sun is at a rate equivalent to the combustion of many thousands of millions tons of coal per second. The modern conception of the sun's generation of heat involves the theory of interatomic action, matter being transmuted into energy; a process quite different from our well known combustion. For millions of years the scientists tell us the sun has been producing heat at about a uniform rate and is likely so to continue for many million years more.

Many efforts have been made to convert radiant heat from the sun into power. A number of small plants have been made to work and several are now reported in operation. In the sunnier climes sun heat is gathered and stored for hot water supply in residences, a perfectly practicable procedure where the sun shines enough hours per year, though usually auxiliary heat is part of the equipment.

Professor Compton states that in temperate zones, during the 3 mo. of greatest sunshine each acre of land receives the heat equivalent of 250 t. of good coal. No doubt some further progress in the utilization of the sun's rays will be made, but there are too many adverse factors to warrant expectation of any significant relief of the world's fuel situation from this direction.

Power from ocean tides and waves has attracted numerous inventors, and promoters have sold their stock to a gullible public. Several small tide power plants are in operation. The old tide mill was good in its day, but the development of this early prototype into large power plants capable of competition with other power sources presents obstacles such as excessive cost, distance from power markets, scarcity of favorable sites, necessity for large storage, low use factor, obstacles so great as to make us try almost anything else first.

Wave motors can be worked to develop power. The regular bell buoys and whistling buoys of navigation are a practical application. So far, all wave power projects have been commercial failures, and engineers

can think of plenty of reasons why wave power plants hold out no important aid in the field of the world's power supply.

Heat of the earth's interior would be a vast source of energy if it could be drawn upon in a practicable manner. It is possible to secure steam from the earth close to active volcanos, and this is done. At Lardarello, Italy, for some years about 7500 kw. has been generated in this manner. Some energy from natural steam is generated at the Geysers in California.

In general it is found that the temperature increase as depth is attained is so slight in most parts of the earth's crust as to offer very small encouragement for the development of this source of heat. The last news in the field is that in one location a twelve mile hole is proposed.

Alcohol

Ethyl alcohol made from various appropriate farm products offers a very interesting and real source of heat and power. It is adaptable to the automotive field of internal combustion engines, is far safer than gasolene and is equally convenient and efficient for stationary power operations and direct heating processes. It is employed today in European countries and even in the United States an important effort is under way for blending 5 to 10 per cent of alcohol with gasolene for motor uses. Such an admixture it is claimed completely eliminates the knock of ordinary gasolenes.

I am informed that in time sufficient crops could readily be developed, grown and harvested annually from which enough alcohol could be distilled to replace all the motor fuel requirements of our country. While I have no statistical data on which to base a prediction, it would seem within reason to imagine a number of centuries from now a production of alcohol on a scale large enough to go a long way toward replacing the then reduced supply of other fuels. Far too costly now of course, but for the distant future a real possibility.

Winds of earth represent a vast and widely spread source of energy. The cost of harnessing their potential horsepower is excessively high at present. The windjammer of clipper ship days reeling off her eighteen knots through the trades was an inspiring example of marine application of wind power.

Obvious difficulties for extensive stationary application are unsteady and low velocity winds where we most need their power. Some quite modern designs of winder power generators have been developed and we may look for further efforts in the future. Improved and less costly storage batteries would aid such projects greatly. Something may be expected from wind power for future generations.

The Ocean

The inventor Georges Claude spent a million dollars trying to get energy from the difference in temperature of sea water at the surface and at a great depth. He succeeded in doing this but the auxiliaries consumed more power than he generated. It was a noble and interesting experiment.

Much research and experiment has been expended toward design of a primary battery to give cheap current. Coal burned direct in an electrolytic cell was another attempt that failed. Success is not yet in sight, but who can say what the years may bring forth?

We can readily conceive of the principle of the thermo couple receiving heat from combustion of fuel in a perfectly insulated bomb, so that the heat could escape from the bomb only in the form of electric current with a consequently nearly 100 per cent conversion. If that could be done, we could heat with electricity from a carbo-electric plant at an efficiency of say 90 per cent with power converted from fuel at equal efficiency, three times our present best. This indeed would substantially extend our fuel resources to say nothing of the marvelous simplification of our present generating stations. Perhaps, some day, something like this will be accomplished.

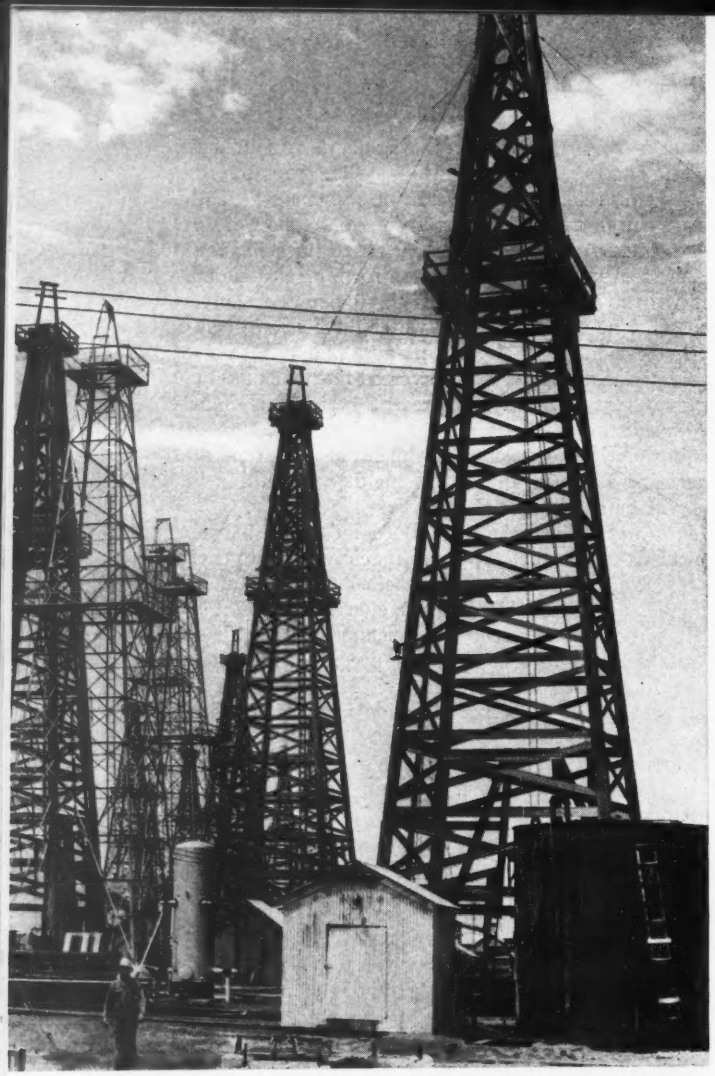
I do not believe the good Lord meant us to waste two-thirds of our fuel supply in its conversion to useful energy, and I believe some process will be found to change heat directly into electric current.

It is certain that the physicists will make discoveries which will revolutionize our present conception of energy and heat and electricity. Much has already been accomplished in this direction in their studies of atomic chemistry and radio activity. We are told that in a pound of coal there are many millions of kilowatt hours of interatomic energy. Can these be released, controlled and utilized? Energy production of this order accounts for the sun's heat and power. We have the same elements on the earth.

Let me quote from Arthur Compton, Nobel prize winner in physics:

> "One of the major problems of the physics of the future is thus to investigate all sources of energy which show promise of being important. A hopeful lead is the inexhaustible flow of energy from the sun and stars in the form of radiant heat. Geological records indicate that for a billion years the sun has poured heat upon the earth at about the same rate as it now comes to us. . . .
>
> "Within the last twenty years several theories of stellar heat have been put forward, the most promising of them based upon atomic nuclear reactions similar to radioactivity. In the laboratory, it has been found that such nuclear reactions can be produced and are capable of supplying heat in the necessary amounts. We do not yet know, however, how these nuclear reactions are made to occur efficiently on the sun, nor have we any assurance that they can be brought about on earth in such a way as to act as a source of energy.
>
> "There is thus no reason to be pessimistic with regard to power supply. It may require a decade, a century, or a thousand years, but there appears no reason to fear man's inability to find an adequate new supply before the failure of power sources now developed limits the advance of society."

In conclusion may I be permitted modestly and hopefully to agree with Arthur Compton that man's future needs for heat and energy will be provided in due course. And in spite of appearing to shift the job to the shoulders of following generations I am inclined to conclude with the scriptural injunction: "Take therefore no thought for the morrow; for the morrow shall take thought for the things of itself".



Oil Wells at Beaumont, Texas
Photo. courtesy of Standard
Oil Co. of Indiana.

The Energy

HUMAN PROGRESS through the ages can be measured by man's ability to turn the energy with which Nature has supplied him into the various forms which accomplish the purposes most desired at the time. All energy available on the earth is believed to have emanated from the sun with infinitesimal additions in the form of cosmic energy which may be neglected so far as availability is concerned. Many billions of heat units reach the earth each year, here to be transformed into other forms of energy—chemical, electrical, mechanical, biological.

During the ages much of this energy has been stored in coal, oil and gas and is convertible into heat. Professor Svante Arrhenius has calculated the total energy available in the world from all possible sources. His estimates are given in Table I.

Most of these sources are of only academic interest since economic means of controlling them have been found for only a few out of the number, these being power energy derived from rivers, from coal, from oil and gas and from the air. In time other forms of energy than these may be brought into economical use but these constitute by far the most important sources of power.

Coal, with its origin in prehistoric ages, is the most important source of power at the present time. In the United States, between 55 and 60 per cent of power generated is from coal. Geologists report that throughout the world the earth contains over 7400 billion tons of coal of which 1.3 billion are being used annually, or a supply sufficient to last some 6000 yr. These deposits are within 3000 ft. of the surface, supplies at further depths have not been estimated, but are most assuredly large and the ingenuity of mining engineers will, no doubt, as need requires make these lower deposits available.

Notwithstanding the vast resources of coal in its various forms, engineers are continuously improving the economy of power generation, a practice tending to conserve the natural supply. Whereas in 1892 the average amount of coal used to generate one kilowatt-hour of electricity in utility plants was 8 lb., at the present time the average is less than 1.5 lb. while in the most modern stations power is generated on less than 1 lb.

Table I. Total energy available in the world

	Billion Calories
1. Solar radiation of heat during the year	$3\times10^{12}\times10^{6}$
2. Solar radiation of heat to earth, including air jacket	1330×10^{6}
3. Solar radiation of heat to the surface of the earth	530×10^{6}
4. Evaporation of water in the oceans and air	340×10^{6}
5. Energy of the water in the clouds	2800×10^{6}
6. Energy of the flowing water	55,000
7. Energy realizable from rivers	4000
8. Energy of the air currents	33×10^{6}
9. Energy stored up in plants	160,000
10. Energy of the coal consumed per annum	10,000
11. Total energy of fossil coal	44×10^{6}
12. Total energy of earth oil deposits	120,000

Modern burning equipment is contributing to conservation by being able to use grades of coal formerly thrown away as of no economic value. Mining methods and coal preparation are also contributing in this direction.

Fuel resources are scattered widely throughout the world but some countries are faced with immediate shortages and, from these, engineers are learning many ways in which to conserve resources. Studies and statistics given here, however, will be confined to the United States as the problems confronting this country are quite distinct from those of other countries.

Resources Of The World

Various forms of coal, petroleum and gas constitute the major sources of power used in industry today. Available water power sites are being developed as economic and social needs indicate. Other sources are but little used.

Looking at the map of the United States showing the known coal fields, it will be observed that 31 states contain mineable coal of various qualities suitable for use with modern burning equipment serving steam boilers. Reserves are estimated at over 3000 billion tons, 25 billion of which have been mined.

Anthracite districts are located in Pennsylvania, Colorado, New Mexico and Alaska. For the production of power, however, the Eastern Pennsylvania field is the only one of great present importance and, due to competitive prices and the technical advances in burning equipment, less of this quality of fuel is being used annually for power generation. The total output of anthracite declined from 93,339,000 tons in 1923 to 49,541,000 tons in 1933, and to 50,037,000 tons in 1937.

By far the most commonly used coal for power generation is that classified as bituminous which occurs in five principal fields and occupies a total area of about 2000 sq. mi.

The best grades, which may be defined as those having the highest heat value and most desirable burning characteristics, are, in general, found in the Appalachian field, the quality becoming poorer in the fields to the west.

Sub-bituminous coals with an original reserve of 818 billion tons, lignite with 940 billion tons and peat with 14 billion tons in the United States are being used but very little in this country. While these fuels are much lower in heat value than other forms of coal and require special combustion equipment, technological developments will, no doubt, make them economically available as the present sources begin to decline.

Transportation of coal from the mines to the steam-electric plant location, usually at the load center of the district served, is an item of expense equal in some localities to the cost of the coal at the mine. The usual means is by steam railways, or rail and water. By either method large quantities of coal are required, contributing to the depletion of the national reserve.

Mine-mouth plants have been proposed as a partial answer to the transportation problem and a number of such plants have been built but such a location has many limitations, the extent of which has not always been appreciated by the proponents. Among the most important factors to be considered are: The expense of building and maintaining the power transmission line to the load center of the system. The building and operating expense of a standby station near the load center to insure reliable and continuous service. The frequently limited condensing water supply at the mine mouth. The available location may be a few miles from the mine, thus requiring car loading, once loaded transportation to a considerable distance is accomplished without much added expense. Construction and maintenance costs are usually appreciably higher in out-of-the-way places at mine mouths than in industrial centers.

Advantages of the mine-mouth location of plants are: Coal transportation is eliminated, thus providing cheap fuel. Ash disposal can usually be accomplished without great expense. Stack gases in the open country are seldom objectionable.

Another method proposed, but not extensively used, for reducing the transportation expense is the gasification of the coal at the mine and piping the gas to the power generating plant. Still another

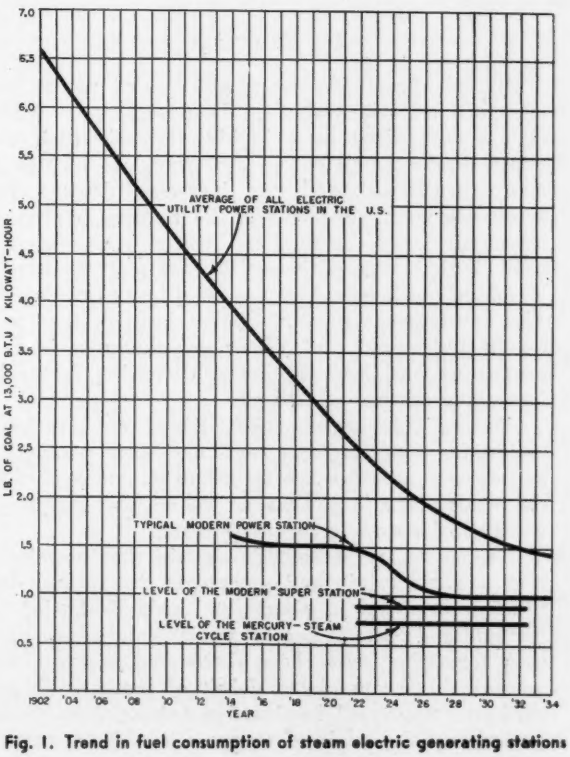


Fig. 1. Trend in fuel consumption of steam electric generating stations

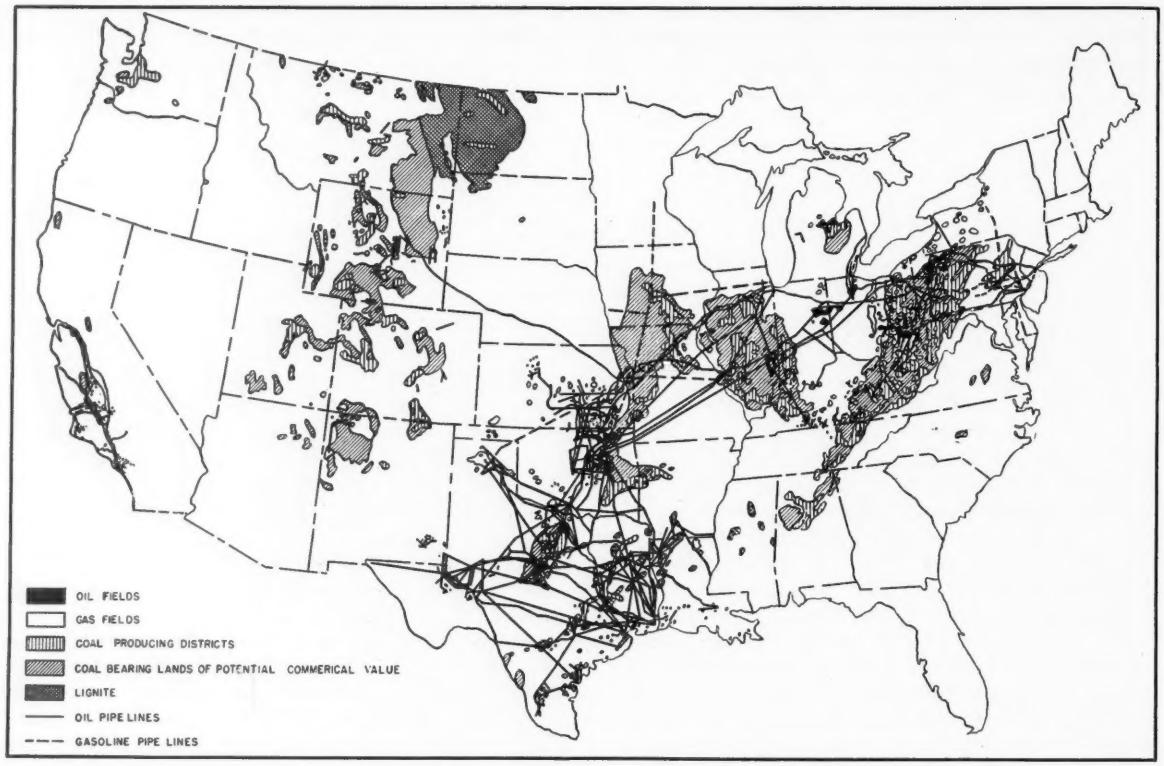


Fig. 2. Coal, oil and gas producing districts in the United States with oil and gas pipe lines

scheme proposed is to pulverize the coal at the mine and transport it through pipes. Either of these would require an expensive pipe line, the economy of which must be justified by the possible savings.

Oil Resources

Oil as a fuel for the generation of power has advanced materially during the past 20 yr. While always recognized as a highly desirable fuel, the relative price compared to coal prohibits its use in many localities. With the increased demand for automobile gasoline, however, the refinery byproduct commonly known as Bunker C can now be sold at a price highly competitive with coal and its use is becoming much more common than in pre-war years. The development of combination burners that will handle pulverized coal, oil or gas singly or in any proportion has been another contributing factor in increasing the use of fuel oil.

During this same period, Diesel engines have undergone many improvements and their popularity as power generators has shown rapid increase with the result that a large share of the oil used for power generation is used in this type of unit.

Geologists are reasonably certain that petroleum is of organic origin and represents the natural distillation products of plants and animals buried in the mud and oozes of ancient swamps and seas. Vast rock formations have been discovered that are unquestionably accumulated debris of innumerable organisms, compressed, hardened and changed into rock. Underlying thousands of square miles of the earth's surface are fossiliferous limestones, phosphate rock and coal seams, which geologists have interpreted as the solid residue of former plant and animal life from which processes of nature have extracted the oils and gases by applying heat and pressure.

Petroleum deposits throughout the world are widespread but today the most commercially important fields are located in the United States, Russia and Mexico, with the Dutch East Indies, Rumania, India and Galicia contributing minor quantities and other countries combined produce little or no petroleum.

With the United States as by far the greatest producer of petroleum, this industry has advanced with extreme rapidity, carrying with it advantages to all manufacturing establishments serving the industry with machinery and steel for pipe lines and construction, giving impetus to the automotive industry which has replaced most of the animal power in the United States, and, in the power generating field, produced fuels that are highly competitive with coal and contributed to the development and wide use of Diesel engines.

Transportation of petroleum from the wells to refineries and from there to points of consumption, first accomplished by rail and truck tanks, is supplemented by numerous pipe lines that now extend from Texas to New York and have been instrumental in making oil truly a national rather than a local fuel.

Near refineries some power plants have taken advantage of the byproducts available and equipped their furnaces for using petroleum carbon in pulverized form.

Economists have expressed grave concern over

the limited natural supply of petroleum and at various times dire predictions have been made as to the time when the nation's petroleum resources would be completely exhausted. As late as 1918 government authorities calculated that the then underground and available reserves under existing methods of recovery were only 70 bbl. per capita, or a supply estimated to be exhausted in the early 1930's. Best estimates today place the available supplies of crude oil in the United States as sufficient to last in the neighborhood of 100 yr.

Potential oil lands in this country alone cover 1,110,000,000 acres with but 2,000,000 acres actually producing oil from depths up to about 2 mi. and geologists have explored less than 2 per cent of the potential oil bearing areas. Notwithstanding this much more optimistic viewpoint on the part of authorities, the development and employment of conservation methods need the consideration of every oil producer and user. Economic limitations alone seem to have stimulated rather than deterred production which has been continuously on the rise.

Technologists of every type are at work in the petroleum industry and improvements are continuously being made in recovery. Refinery practices are making possible more efficient use of crude petroleum and thus conserving the supply.

It has been estimated that 22 per cent of the total energy used in the United States is derived from petroleum. In the neighborhood of 45 per cent of the crude oil refined in the United States is used as gasoline in motor cars, airplanes, motor boats and Diesel engines.

Natural Gas

Closely allied with petroleum as a source of energy for power generation is natural gas. Allied because it is almost invariably found in the vicinity of oil or coal deposits. In the United States this gas is being produced at the rate of about 1.6 trillion cu. ft. per year and the North American supply in present fields is estimated at about 75 trillion cu. ft. or, roughly estimated, enough to last 50 yr. This again is of grave concern and calls for extreme conservation measures. So long, however, as the oil and coal supplies hold out, manufactured gas may readily take the place of natural gas as a fuel for the generation of power.

In many ways gas is an ideal fuel both for burning in furnaces for the production of steam and in internal combustion engines for developing power direct. Transportation is readily accomplished by pipe lines without excessive friction loss. It needs no preparation before burning other than the maintenance of pressure and the proper mixing with combustion air. Burner and furnace designs suitable for gas are of the simplest sort. Combustion can be efficiently accomplished without the production of smoke, seriously objectionable gases, slag or ash of any kind. Perfect combustion control is readily accomplished. So advantageous are the features of gas as fuel that within the past few years, especially since pipe lines from the southwest fields have been extended to serve the industrial sections of the midwestern states, the power generated from gas as fuel has increased enormously, as will be observed in Table III.

As a fuel competing with either coal or oil, natural

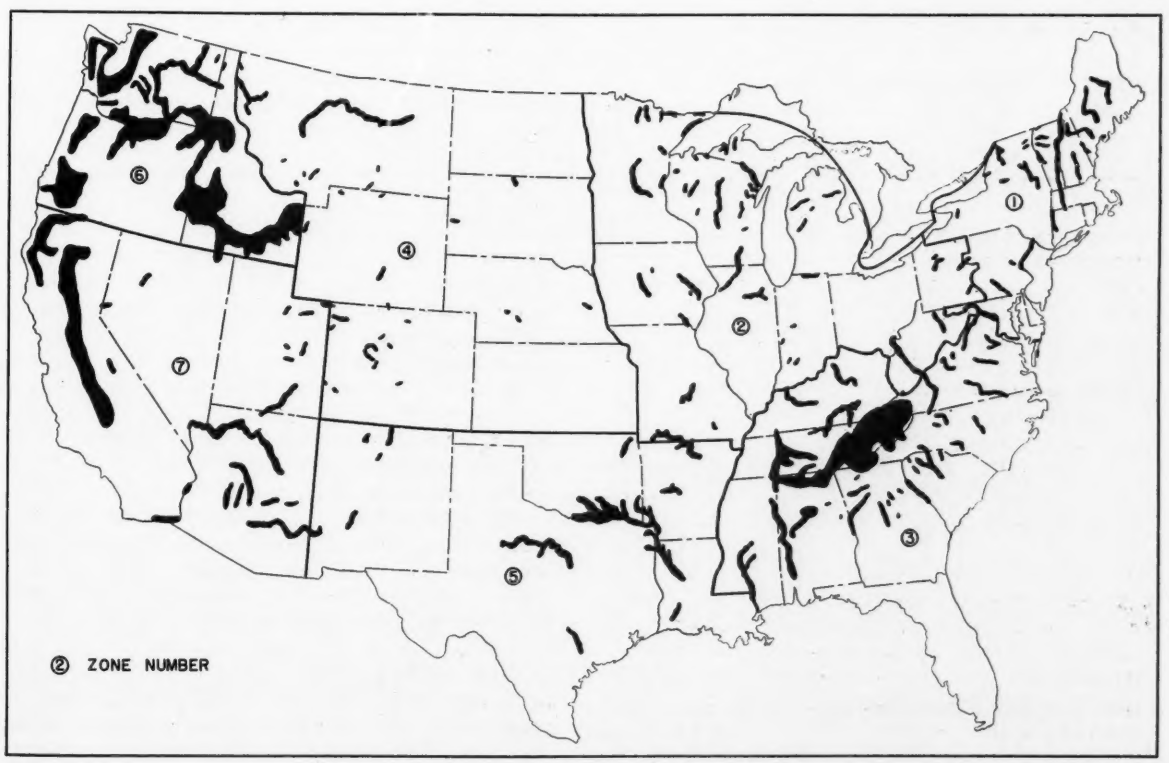


Fig. 3. Location of undeveloped water power areas

Table II. Estimated mineral fuel resources of the United States

Description	Original Reserve	Reserve End of 1935	Per cent Exhaustion	1929 Production
Anthracite, billions of net tons[a]	22	16.5	25	0.074
Low-volatile bituminous coal, billions of net tons[b]	56	.....	4	.....
High-volatile bituminous coal, billions of net tons[b]	1378	.....	1.6	.....
Subbituminous coal, billions of net tons	818	.....	0.05	.....
Lignite, billions of net tons	940	.....	0.01	.....
Total, all ranks of coal, billions of net tons	3215	3185	0.9	0.609
Petroleum, billions of bbl.[c]	31 ?	13 ?	58 ?	1.007[d]
Oil in oil shale, billions of bbl.[e]	92	92	0	0
Natural gas, trillions of cu. ft.[f]	80[g] ?	40 ?	50 ?	2.5[h]

[a] M. R. Campbell, "Coal Resources of the United States," U. S. Geological Survey Mimeographed Report (1928).
[b] Includes some medium volatile coal.
[c] W. L. Baker, "U. S. Crude Reserves Enlarged During 1935," *Oil Weekly*, Vol. 80, February 10, 1936, pp. 19-22. Proved reserves based on the amounts recoverable with present methods of production.
[d] 79 million bbl. of crude petroleum were imported; 26 million bbl. of crude petroleum and 123 bbl. of refined products were exported in 1929.
[e] D. E. Winchester, "The Oil Possibilities of the Oil Shales of the United States," *Report II*, Federal Oil Conservation Board, January, 1928, pp. 13-14.
[f] V. H. Garfias, *Transactions*, Am. Inst. Mining and Metallurgical Engrs., Vol. 114, pp. 243-244 (1935).
[g] Includes 8 trillion cu. ft. blown into the air and wasted, *Petroleum Times*, Vol. 33, p. 346 (1935).
[h] Includes one-half trillion cu. ft. blown into the air and wasted.

gas has the disadvantages that transportation must be made by pipe line, and storage in great quantities is impracticable. For these reasons it was not until the completion of the gas transmission pipe lines that this fuel was available beyond local communities.

Water Power

Although one of the oldest sources of power utilized to perform work for mankind, falling water is still one of the most used and most efficient available sources in use today. Before the advent of electric power, industries using water power were compelled to be located by a waterfall or a swift moving stream that could be dammed to create a waterfall. With electricity almost completely removing this disadvantage great sources of power have been made available that were too remote from industrial centers to be of real value as a power source. Transmissiou losses, however, still limit some otherwise available water power sources, but here is one great source of power that cannot be depleted by using it to its fullest and, although fluctuating greatly in many cases, its constancy of volume can be reasonably estimated so as to permit calculation of a plant capacity that will give relatively constant service.

Estimates of the potential water power resources vary greatly. Authorities reporting at the World Power Conference in 1927 gave the figure of 444,574,000 hp. as the world's total based on a 90 per cent continuous flow during the year, while for the United States on the same basis the potential water power was given as 38,110,000 hp. In 1936, however, the U. S. Geological Survey gave an estimate based on the installation of water wheels at fully developed water power sites, stating that water wheels with a capacity of about 80,000,000 hp. would be required to make use of all the potential water power in the United States. Since at that time there were installed water wheels having a total capacity of only 16,079,407 hp., it was estimated that water power resources were only 20 per cent developed.

Table IV, presented in the Federal Power Commission, National Power Survey, Interim Report of 1935, stated as not to be considered precise or final, gives an idea of the undeveloped water power in the United States, particularly when read with the map, Fig. 3, in view. In estimating the installed capacities, it is stated, consideration was given to the character of the load to be supplied, the variation in the stream flow, the possibility of storing water, and other factors. Sites that could not be economically justified, in the judgment of the Commission, were omitted from the table.

Flowing streams account for almost all the water power developed, there are, however, minor amounts of power generated by the flow of tidewater, ocean waves and even artesian wells. In but few instances, these sources may be neglected as of little importance. Notable among the tidal sources is the Passamaquoddy project undertaken by the United States Government but abandoned before completion.

Water power is one of the most valuable resources the country possesses and may be depended upon to last throughout the ages. As will be noted in Table III it accounts, at the present time, for 35 to 40 per cent of the electric power generated for public use and will

Table III. Generation and fuel consumption covering plants of electric light and power enterprises, electric railways, public works and manufacturing establishments contributing to the public power supply

(As Reported by Federal Power Commission Since 1936 and by U. S. Geological Survey for Prior Years)

Year	Kilowatthours generated (Millions) Total	By Fuels	By Water Power	% Hydro	Fuel Used (Thousands of Units) Coal (Short Tons)	Oil (Barrels)	Gas (M Cubic Feet)	Relation Fuel Used to Generation: Generation by Fuel (Excl. Wood) (Kw-hrs.)	Fuel Used in Coal Equivalent (Short Tons)	Pounds per Kw-hr.	Per Cent of 1919 Rate
1937*a*	**120,996**	**77,289**	**43,707**	**36.1**	**44,768**	**14,029**	**171,188**			**1.43**	**44.7**
1936	113,602	72,665	40,937	35.8	42,025	14,119	156,080	72,188	51,987	1.44	45.0
1935	99,398	59,430	39,968	40.2	34,807	11,393	125,239	59,176	43,188	1.46	45.6
1934	91,150	57,092	34,058	37.4	33,555	10,379	127,896	56,914	41,266	1.47	45.9
1933	85,402	50,674	34,727	40.7	30,575	9,940	102,601	50,542	37,163	1.47	45.9
1932	83,153	49,055	34,098	41.0	30,290	7,967	107,875	48,931	36,600	1.50	46.9
1931	91,729	61,126	30,603	33.4	38,734	8,123	139,328	60,768	47,134	1.55	48.4
1930	95,936	62,915	33,021	34.4	42,898	9,260	120,290	62,514	50,654	1.62	50.6
1929	97,352	62,723	34,629	35.6	44,937	10,124	112,707	62,284	52,574	1.69	52.8
1928	87,850	53,154	34,696	39.5	41,350	7,158	77,326	52,793	46,387	1.76	55.0
1927	80,205	50,330	29,876	37.2	41,888	6,782	62,919	49,995	45,910	1.84	57.5
1926	73,791	47,602	26,189	35.5	41,311	9,399	53,207	47,274	45,856	1.95	60.9
1925	65,870	43,514	22,356	33.9	40,222	10,246	46,521	43,264	44,780	2.10	65.6
1924	59,014	39,044	19,969	33.8	37,556	16,630	48,443	38,808	43,130	2.20	68.8
1923	55,665	36,322	19,343	34.8	38,966	14,684	31,433	36,088	43,522	2.40	75.0
1922	47,654	30,447	17,207	36.1	34,179	13,197	27,172	30,234	38,000	2.50	78.1
1921	40,975	26,005	14,970	36.5	31,585	12,045	23,722	25,863	35,240	2.70	84.4
1920	43,555	27,405	16,150	37.1	37,124	13,123	24,702	27,248	41,420	3.00	93.8
1919	38,921	24,315	14,606	37.5	35,100	11,050	21,406	24,175	38,880	3.20	100.0

(a) FPC News Release No. 366.—2/2/38.

probably reach a higher percentage than this when full advantage can be taken of projects now under construction by the Federal and local governments.

Power from Men and Animals

In a survey of our world's power resources, human and animal power cannot be neglected. Although industrial development has always been toward the elimination of man power, machines have not yet reached the stage of development where they can economically entirely replace man and animal power. In the agricultural, construction, mining and road building fields both man and animal power play an extremely important part. In factories and transportation fields mechanical and electrical power are the dominating sources. It is estimated, however, that in the United States, 4 per cent of the energy used is derived from men and animals, throughout the world this percentage is greater since the United States is the most highly mechanized country in the world.

Table IV. Undeveloped water power in the United States

Zone	Region	Number of sites	Estimated average annual output 1,000 kilowatt-hours	Estimated installed capacity, kilowatts
	1	2	3	4
1	Northeast	327	21,075,000	5,886,100
2	Middle West	234	13,203,000	3,604,600
3	Southeast	369	41,112,000	10,826,000
4	Mountain and Plain	93	15,992,000	3,431,300
5	Southwest	83	6,301,000	1,522,900
6	Pacific Northwest	528	114,200,000	15,664,000
7	Pacific Southwest	249	63,800,000	11,694,000
	Total	1,883	275,683,000	52,628,900

Wind Power

Wind, as a source of power, is one of the earliest forms used by man having been extensively employed for propelling ships, pumping water and grinding grain. Of more recent years, wind has been the source of energy for driving electric generators for farm lighting and radio sets. This source of power, however, is extremely erratic and cannot be depended upon as a steady supply. Water, of course, can be stored so that wind makes a very satisfactory source for pumping purposes where service demands are not rigid as is the case on farms and in small villages. Methods of storing electric energy have not as yet been developed to the extent that wind power alone can be depended upon as a reliable source of energy in competition with other forms now available. Wind, however, even with its advantages of low operating expense, wide availability, and inexhaustible supply, is estimated to be furnishing only about 1 per cent of the energy used in the United States.

Windmills for the generation of electricity have been built with capacities ranging from 1 to 75 hp. In some foreign countries units have been built that deliver as much as 300 hp. and many experimental developments have been made in an effort to make further use of this power. Other methods of generating power for industrial purposes have proved more satisfactory and it is not likely that this enormous source of power will be used extensively until some means of storing power is developed that will permit this system to be employed economically in competition with fuel generated power.

Power Sources Little Used

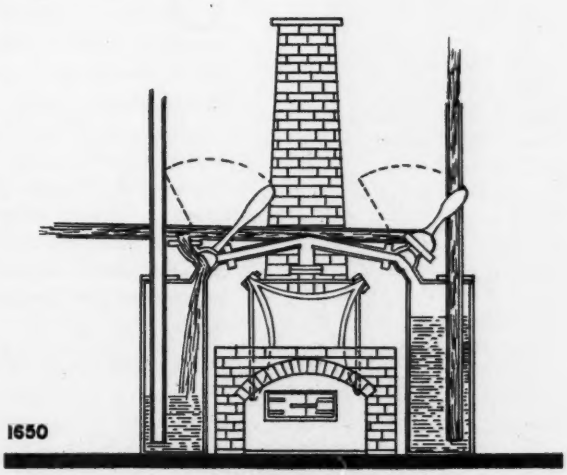
Scientists have given study to grain produced alcohol and cellulose as a source of power and while this source has its possibilities as a supplementary source it cannot, today, compete with other fuels in an economic way.

Energy direct from the sun as a source of power for industry is still to be successfully applied. Isolated experiments with equipment designed to convert the sun's rays into steam and electric power have met with academic success but industrial applications are still to be made before this method of securing power can be seriously considered even though the sun is the source of all the earth's energy.

Power has been produced in some localities in Italy and California from steam generated by heat from the internal rocks of the earth. While limited as to location and offering some engineering difficulties, this source of energy is directly applicable to industrial uses with future possibilities as yet unknown.

At present academic in its importance, atomic energy is receiving increasing attention from scientists as a possible source of power for future generations. It appears today that more energy is required to crack atoms than would be given off for conversion into usable power. Only time will reveal the results of experiments now being conducted.

Present known fuel sources of power are sufficient to last for possibly thousands of years. Economic changes will undoubtedly shift the rate of use from one fuel to another or cause the conversion of coal into oil or gas but there is every evidence that technological developments and human ingenuity will meet all the problems as they arise so that a shortage of power resources to carry on the nation's industry is an extreme possibility.



The Marquis of Worcester was the first to actually construct a practicable steam engine

Photo, Jones & McLaughlin.

The Rise

It is a far cry from the crude flint implements of the paleolithic age to the modern rolling mill but the use of these crude flints marked the beginning of an educational process that would some day enable man to harness power in practically unlimited amounts.

OUR TIME is rich in inventive minds, the inventions of which could facilitate our lives considerably. We are crossing the seas by power and utilize power also in order to relieve humanity from all tiring muscular work. We have learned to fly and we are able to send messages and news without any difficulty over the entire world through electric waves.

However, the production and distribution of commodities is entirely unorganized so that everybody must live in fear of being eliminated from the economic cycle, in this way suffering for the want of everything. Furthermore, people living in different countries kill each other at irregular time intervals, so that also for this reason any one who thinks about the future must live in fear and terror. This is due to the fact that the intelligence and character of the masses are incomparably lower than the intelligence and character of the few who produce something valuable for the community.

ALBERT EINSTEIN,

His message to posterity, sealed in the Time Capsule at the N. Y. World's Fair, September 21, 1938.

In Man's Use Of Power

IN TRACING the rise in man's use of power from the earliest beginnings to the present advanced state of technical development, we are dealing with a process that is of far greater universal significance than might be suspected from a casual consideration of the subject. For power is a manifestation of energy, and energy is the all important entity in the Universe, the one thing in fact of which the Universe appears to be made. Everything we do, everything we are, everything in the world upon which we depend for life and comfort seems in some way to be related to this matter of energy. The second law of thermodynamics seems to be as intimately interwoven with our existence as it is with the rotation of a turbine rotor. Energy flows downward through matter, and life itself appears to be merely a manifestation of this downward flow—an accidental consequence, perhaps, of the special set of laws by which the universe is governed. Society, the organization of men and animals, is itself a sort of pattern of energy which exists by virtue of the downward flow of energy in a way not unlike that in which a flame exists in a furnace. Power is the dynamic manifestation of energy—of energy seeking a lower level.

The extent to which energy is involved in our existence is only dimly appreciated by the millions who live and die upon this planet. The food we eat and which plants produce from the soil and air, we know, is the fuel by which we live and grow and is involved with energy relations, but few of us give the matter much more consideration. And yet energy is involved in many other aspects of our existence. Only within recent years have we come to realize how important a part the energy of sunlight plays in our bodily processes and today evidence is accumulating which may show that the process of natural selection in the evolution of plants and animals is due to the action of the energy of cosmic rays upon the germ cells before birth. The role of energy in controlling the fitness of our environment cannot be realized until we delve deep into the mysteries of nature. The energy of the sun seems to interact with every phase of our existence and often with a delicacy of control that is astonishing.

We live, it seems, by a very narrow margin of safety in a universe which appears to have little concern for us. When we contemplate the universe from the standpoint of modern physics we are appalled by the almost limitless odds against us. Viewing it from the microscopic grain of matter we call the earth our first impression is one of terror. We are terrified at the incalculable vistas of time which dwarf human history to the twinkling of an eye; we shrink from the thought of our extreme loneliness and the material insignificance of our home in space, but above all else, we are terrified by the indifference of the universe to life as our own. For, nowhere in it—nowhere in all those inconceivable stretches of space and time do we find anything that even remotely resembles life like our own. Emotion, ambition, achievement, hope, love, religion, all seem to be foreign to the plan, if plan there be. Indeed, the whole thing seems to be actively hostile to life such as our own.

Yet into such a universe we have stumbled, if not exactly by mistake, at least as the result of an accident —an accident so improbable that it seems very unlikely that in all of space there is another world on which a similar accident of life could have occurred. On this planet we live, shielded from the intense heat within by a thin, rocky crust, and from the intense cold and harmful radiations without by a thin film of life-sustaining atmosphere. But even for these protective elements we should still die were it not for the one bright element in the scheme that brings us some degree of cheerfulness and assurance—the Sun.

As pointed out in the introduction to this issue, we owe practically everything we are and have to the sun. All our energies step off from the sun. The origin and evolution of all life was brought about by the energy of the sun. By the aid of its light and warmth man evolved from a brute animal into a rational being, one not without shortcomings perhaps, but still the only one of all the creatures on earth not bound by the current terms of his environment, and, by the same token, the only one who has become able to direct the energies of the sun to serve his purposes. For though man may stand in terror at the enormity and the indifference of the universe, he does not hesitate to harness the energies of the universe for his benefit.

From the earliest beginnings when man first became a tool maker he has constantly advanced in the direction of an increasing use of the sun's power, first by utilizing the indirect energy of the sun in the wind and water and later by the use of the stored solar energy in the fossil fuels.

It is this story of the rise of man's use of power that we propose to tell in the pages that follow; how through the ages he gradually learned and became aware of the laws and conditions controlling the release of energy and how he learned ways of using it. It is a story that has its beginnings in the dim dawn of pre-history and the end of which still remains to be told. In telling it, we shall endeavor to trace the influence of various discoveries and developments as they occurred, not in detail but in outline so as to present a picture of the history of power as a whole in proper perspective. It is a story of fascinating interest, not so much for what it tells us of the past, but for its implications in regard to the future of the human race. For in the realm of power man seems to have advanced continuously from early times and if this advance is to continue into the future, only the gods can envision the heights to which man may climb during his tenure upon this planet.

The Rise of Power

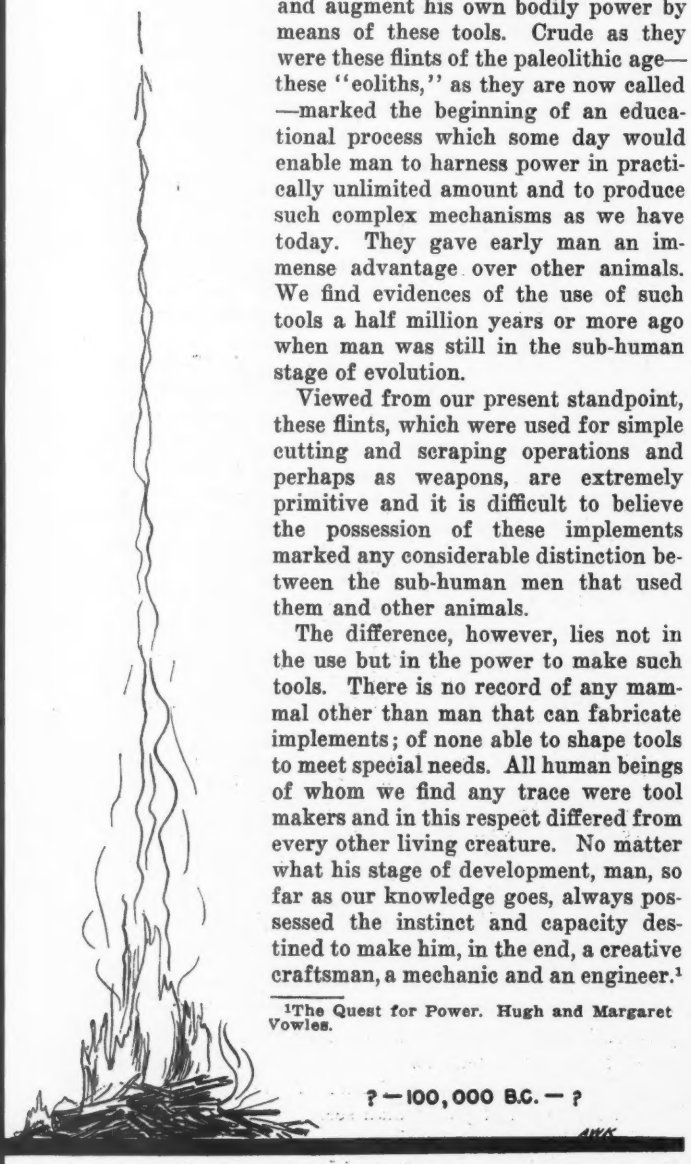
Tools and Fire

MAN'S EARLY steps along the long road leading to his use of external power were made unconsciously; he had no idea that what he was doing would lead him anywhere. From the earliest records we can find, however, we find evidence, in the form of flint tools, of his endeavors to extend and augment his own bodily power by means of these tools. Crude as they were these flints of the paleolithic age—these "eoliths," as they are now called—marked the beginning of an educational process which some day would enable man to harness power in practically unlimited amount and to produce such complex mechanisms as we have today. They gave early man an immense advantage over other animals. We find evidences of the use of such tools a half million years or more ago when man was still in the sub-human stage of evolution.

Viewed from our present standpoint, these flints, which were used for simple cutting and scraping operations and perhaps as weapons, are extremely primitive and it is difficult to believe the possession of these implements marked any considerable distinction between the sub-human men that used them and other animals.

The difference, however, lies not in the use but in the power to make such tools. There is no record of any mammal other than man that can fabricate implements; of none able to shape tools to meet special needs. All human beings of whom we find any trace were tool makers and in this respect differed from every other living creature. No matter what his stage of development, man, so far as our knowledge goes, always possessed the instinct and capacity destined to make him, in the end, a creative craftsman, a mechanic and an engineer.[1]

[1]The Quest for Power. Hugh and Margaret Vowles.



The use of fire was a discovery of major importance

For many centuries—for tens of thousands of years in the interglacial periods—the primitive races of man possessed few other tools than these flints. If the Heidelberg jaw was that of a Neanderthal man and if there is no error in the estimate of the age of that jaw, the Neanderthal race lasted for more than 200,000 yr. In this period, man probably also discovered the use of fire which marked another step forward and further increased the difference between man and animals.

Fire, no doubt, had long been familiar as a wonder and as a menace before man used it or made it at will. It may first have been secured from a burning forest or from a tree struck by lightning. The chance ignition by sparks from two flints struck together may have suggested the deliberate kindling of a fire, but this probably came later. Still later would come the production of fire by means of friction—by the use of a simple fire drill, a spindle twirled by means of a bow, or the fire plow consisting of a stick held at an angle and rubbed vigorously in a grooved piece of wood. Just how man discovered that heat is produced by friction is not known, but it must have been accidentally. It is quite possible that the use of fire was discovered, lost, and rediscovered several times before it finally became a permanent part of man's culture.

The use of fire, obviously, was a discovery of major importance, perhaps the greatest that separated man and the animals. At first it provided only a means of warmth, but in time, accidentally probably, man discovered that he could cook his food by fire; as Van Loon suggests, a dead bird may have fallen into the fire and upon removing it later it was found that the fire had improved its flavor and eating qualities or it may have been that the bodies of roasted animals trapped in burning forests were found to taste better than raw flesh. So cooking began and man drew still farther away from the animals. The use of fire enabled man to live in greater comparative security, in caves, and during the long winter days and nights when he could not hunt he utilized his leisure in developing still better tools. The cooking of his food led to a reduction in the muscles used in masticating his food and so facilitated the frontal development of his brain.

The time involved in all this development was prodigious. European man at this time was still liable to attack by the mammoth, the elephant and other animals with which he must have been in constant conflict. Thousands upon thousands of years passed.

As the last glacial ice retreated far to the northward about 20,000 yr. ago, the climate in Europe underwent a marked change. The Mediterranean Sea came into fullness and a general sinking of Europe took place. Heavy forests appeared and a new type of man advanced from the South or Mediterranean basin. This new type of man is known as neolithic (new stone), characterized by his polished stone implements. This marked the beginning of civilization—the introduction of agriculture, pottery, domestication of animals, tool grinding, the bow and arrow, weaving in linen and wool and the establish-

ment of a commonweal existence as evidenced by hut-like dwellings.[2]

The Neolithic period extended down to probably as close to our times as 2200 B. C., but long before that a new period had begun to make its appearance. As far back as 5000 B. C. metals had come into use. Hammered copper tools were in use in Sumeria and Egypt as early as 5000 B. C. As a matter of fact, though we speak of the various ages—the Eolithic, Paleolithic, Neolithic, Bronze Age, etc.—these periods were not necessarily as separate and distinct as the terms imply. There was considerable overlapping. Copper, bronze and iron were probably used long before man relinquished stone.

The point of great importance is that some time between 1200 and say 5000 B. C. man reached an important turning point in his apprenticeship to toil. The use of metals, pottery and the art of weaving gave him undreamed of outlets for his latent constructive powers. Neolithic man was speedily acquiring a much greater range of skill, making experiments, testing materials, becoming more methodical, seeking new ways of satisfying his more diversified needs, showing an appreciation of form and feeling his way over the forces of Nature.[3] In short, he was becoming more of an engineer.

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[2]Chemistry Triumphant. William J. Hale.
[3]Quest for Power.

The Rise of Power

Wind and Water

WHILE man was advancing in other parts of the world, we must now turn our attention to developments of highest importance which were taking place in those regions now known as Egypt and Mesopotamia. For in addition to many other things it was here that the beginnings of hydraulic engineering were made. Just how these civilizations were formed is not known and it is still doubtful whether Mesopotamia or Egypt was the earlier scene of two parallel beginnings of settled communties living in towns, but the records show that by around 4000 B. C. in both of these regions such communities existed and had been going for a considerable time.

The first condition necessary for a real settling down of Neolithic men was a trustworthy, all-the-year-round water supply, fodder for animals, food for themselves and building material for their houses,

Windmills were used for grinding grain in Europe in the 12th century

and nowhere in any of the countries now known to us were these favorable conditions found upon such a scale and nowhere did they hold so good, so surely, year in and year out, as they did in Egypt and in the regions between the upper waters of the Euphrates and the Tigris Rivers and the Persian Gulf.

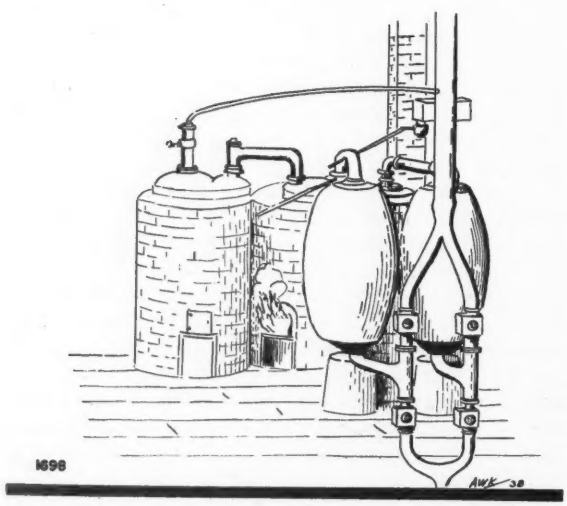
It was natural, therefore, that in these regions men ceased to wander almost unawares, multiplying and taking root. But though the Nile was the source of all water in Egypt, as the population grew, it was found that the natural system of irrigation provided by the annual overflowing of the river was inadequate.

Out of these imperfections of natural irrigation came that impetus to invent, devise, and circumvent—forces which produced in ancient Egypt the earliest known large scale engineering works. The continuous existence of large groups of people became possible only when determined efforts were made to regularize the flow of the Nile, to distribute the water in suitable quantity when and where it was required. Much of the land that could be cultivated was above the flood, and since there was almost no rain, the Egyptians had to develop a system of irrigation. And it was a splendid system that they developed; indeed, not until well in the 19th and 20th centuries of our present era do we find anything to equal the control achieved in Egypt in ages long gone by. The whole country was cut up into oblongs by raising dykes which varied from 12 to 20 ft. in height. Specially high dykes were made along the river banks. By cutting through these, water could be admitted to the basins where it was allowed to stand for a month or so, depositing its invaluable burden of silt. Where the land was above the level of the normal flood, water had to be raised artificially, and this was, and is still, done by means of an apparatus now known as the shaduf. This machine was much like the well sweep to be seen in country districts and consisted merely of a pole pivoted about the center between two upright posts, a bucket being attached by a rope to one end of the pole, and a counterweight to the other end. The bucket is pulled down by hand, filled by dipping, and then raised to the height required by the help of the counterweight. At times probably these shadufs were arranged in relays as they are today, one feeding another, when water had to be raised to unusual heights.

The Egyptian shadufs were among the first of man's attempts to utilize mechanical principles, but as yet no attempt had been made to utilize external power that was available except perhaps that of the wind in propelling boats. From paintings on early Egyptian pottery we learn that boats were familiar objects on the Nile in prehistoric times and though sailing ships were rare, they were not unknown. The sailboat undoubtedly was man's first successful attempt in utilizing natural power other than that developed in the muscles of animals and men. Large ships were navigating the Nile in the first and second dynasties (4000 B. C.).

The water wheel—a simple wheel rotated by the current of a river and used for raising water also came into use at an early date, probably long before any of which we have an actual record. The use of sails and water wheels no doubt led to the development of the windmill. Hero (120 B. C.) describes an apparatus which appears to have incorporated a wheel fitted with vanes rotated by the wind.

There are scattered records of all these things which show that for centuries before what we may call the historical period, man was acquiring knowledge in the use of simple machines, tools, and materials which were destined to effect an incalculable reduction in the sum of human labor. But up to the first century B. C. he had little realization of the possibilities of using external power. This came very slowly. The idea that it was possible to relieve mankind of the burden of bodily toil was still far beyond his mental horizon. Animal power came into use, first for simple transport and with the introduction of circular motion, for other purposes. The first known reference to a mill turned by an ass is in Plantus, one of the greatest Roman comedy writers. In this mill, about 224 B. C., the ass was hitched to a horizontal pole which turned the upper stone as the ass walked around it. Frequently instead of the ass the work was done by slaves and criminals. The first known application of the water wheel to turning mills for grinding grain is probably that mentioned in the epigram of Antipater of Thessalonica which was written perhaps as early as 85 B. C.



Thomas Savery developed the first steam engine to be used in industry

The Rise of Power

The Gradual Awakening

FROM THE FOREGOING it is quite obvious that during the thousands of years preceding what is now called the Christian era man's progress was exceedingly slow as far as the use of external power was concerned. Up to the beginning of somewhere around the first century B. C., we have seen only the most primitive forms of wind and water power had been developed. And this state of affairs was to remain for another ten centuries. The developments that have been mentioned were all made in the ancient civilizations in the regions around the Nile and the Euphrates. In England another thousand years was destined to pass before the first wind mill appeared. The first authenticated date for a wind mill in England was A. D. 1191, and despite the fact that the principles of a simple form of steam engine were described by Hero of Alexandria around 120 B. C., as far as we know, it was not until around the 17th century A. D. that any definite attempt was made to put the principles of steam power into practice.

This slow rate in the use of external power, however, does not necessarily imply that man was not advancing in other ways. As a matter of fact he was developing along many lines, particularly in the use of tools and the knowledge of materials. Man's first tools, we have seen, were made of stone; next he began to shape bits of bone and ivory and also, no doubt, wood. In the records left by that group known collectively as "Reindeer Man" because of the many fine drawings of reindeer which they made and who appeared in Europe probably 20,000 yr. ago, are some very fine bone and ivory tools—needles, pins, spearheads, etc. Agriculture had not yet begun nor was there any domestication of animals but there were rough shelters of branches and skins. Skins also, no doubt, were being stitched together to form garments of a rough sort. Drawings show that these people were keen observers and good artists.

Reindeer Man disappeared but was followed by a race now known as the Azilians who left traces of their wanderings in southwest Europe. From painted pebbles they left behind, it is believed that they used some form of counting.

Whatever the reason and wherever the place of origin, we find that by around 3000 B. C. civilization of a high order existed in several regions of the world. We have already referred to the developments in Egypt. Parallel with the ancient beginnings of culture in Egypt, a similar process was going on in Babylonia, in China and in India, and while intercourse between these various regions was feeble, there must have been a certain interchange of ideas, materials and practices which gave each the benefits of the other's developments.

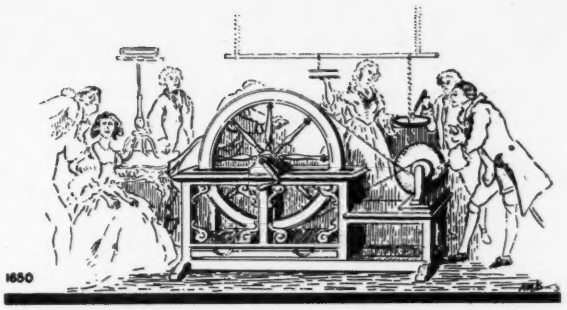
In his "Men and Machines," Stuart Chase lists the

things with which an ancient Egyptian gentleman by the name of Ptah-hotep was familiar in 3000 B. C. "Though unacquainted with iron, he was an expert metallurgist in the less refractory metals. He could smelt them, draw them into wire, beat them into sheets, cast them into moulds, emboss, chase, engrave, inlay and enamel them. He had invented the lathe and the potter's wheel and could glaze and enamel earthenware. He was an expert woodworker. . . . an admirable sculptor. and painter. He was the world's mightiest architect in stone. He made seagoing ships . . . had devised the loom. His language was rich, and he engrossed it in the handsomest system of written characters ever produced on excellent paper. . . . He had numerous musical instruments . . . a metal currency. He had invented most of the hand tools now in existence. He had domesticated animals, was a skilled farmer and a skilled irrigation engineer. . . . He had some of the loveliest furniture the world has ever seen and had cut and polished precious stones. And he had worked out the rudiments of astronomy and mathematics."

None of this knowledge was lost—all of it, in principle at least, has been handed down to us. In the intervening centuries between the time of Ptah-hotep and the beginning of the Christian era, many other developments took place.

Came the Greeks. The Greeks appear in the dim light of the dawn of history (say 1500 B. C.) as one of the wandering imperfectly nomadic Aryan peoples who were gradually extending the range of their pasturage southward into the Balkan peninsula. They did not grow a civilization of their own, but came into a world whose civilization was already there. They wrecked the one they found and put another one together upon and out of the ruins of the old. It is frequently contended that the Greeks were not inventive and that they all held, with Plato, that it was undignified to put one's knowledge to practical use, but there is considerable evidence to the contrary. It is true they engaged widely in commerce and in the fine arts and probably only the poorer free citizens actually followed the mechanic arts for a living, but much evidence is available to show that they made numerous ingenious machines and structures. Certainly they were interested in these things as well as in theories of government, philosophy and science from a theoretical standpoint.

This last point is important. As has been pointed out, a preliminary groundwork of elementary science —hydraulics, mathematics, astronomy—had been laid by the older civilizations of Egypt and Mesopotamia. Even the crude beginnings of medicine, chemistry and mechanics existed long before the Greeks began to speculate about these things. But the Greeks *did* speculate and that is the important point to bear in mind; whereas their predecessors had been content with isolated fragments of empirical knowledge, it remained for the Greeks to give rational explanations of natural phenomena, and to show that by the guidance of first principles and logical reasoning, seemingly independent events might be linked together into an orderly system of cause and effect. It was in fact Thales of Miletus who is often called the father of Greek science and who first noticed the phenomenon of electrification, who first



The strange force of electricity was beginning to excite men's minds. Here is shown Otto Von Guericke's electrical machine in 1650.

gave expression to the conviction that there must be some great unifying principle which links together all phenomena. Thales, thus, envisioned the electron theory centuries before the first evidence of electronic phenomena became known.

With the Greeks for the first time, as far as we know, man became aware of an orderliness in nature which it seemed could be understood and controlled. The Egyptians were skilled in many arts but whatever progress they made was due to intuition and the slow lessons of practical experience rather than to rational thinking. In everything they did they were surrounded by shadows and mysteries, ominous and alive with baffling powers which could only be overcome by incantations, propitiated by ritual and sacrifice. So aside from whatever else the Greeks contributed to the advance of the mechanical arts, our greatest debt to them is for the advances which they made in the realm of thought.

The Romans were even more skilled in the mechanic arts than the Greeks and their roads, bridges and aqueducts remain remarkable examples of civil engineering to this day. They devised numerous machines and were the inventors of the revolving millstone which, figuratively as well as literally, revolutionized the art of milling. They developed ingenious machines of war among which was a torsion machine gun for shooting a succession of arrows by merely turning a handwheel.

Indeed, with our present historical perspective it appears that the Graeco-Roman period had most of the fundamentals for the development of an industrial civilization, yet the industrial age as we know it was not to be born for another twenty odd centuries. Why was this?

A number of reasons can be advanced, but the most likely is the one advanced by Stuart Chase and that is that the industrial age was not born in either the Egyptian or Graeco-Roman period because it was not needed. Though the Greeks seem to have been clever inventors, they did not put their inventions to much practical use. With a vast supply of drafted peasants and slaves to do the most colossal tasks with the simplest tools, the Egyptian and Greek gentlemen were content to let well enough alone. And, after all, what need had the Romans of devising labor saving machines? They needed roads and aqueducts, yes, and they built them, but wherever their legions went two sorts of captives were always brought home—fine women and skilled artisans.

The Rise of Power

The Expanding Power of Gases

NOW, we come to the next great phase in man's rise in the use of power—that phase concerned with the use of the expanding power of gases. Of all the inventions which have marked man's progress along the long road toward the rise of power, the two that have had the most startling effect were made in comparatively recent times. The first of these was the use of expanding gases and the second the electrical transmission of power. The second is linked with the discovery of electromagnetic induction of which we shall learn more later.

When we think of the power of expanding gases our first thought perhaps is of the steam engine and James Watt. Now, the work of James Watt was of immense importance in the development of the steam engine but a process of evolution had been going on before his time which prepared a crude and primitive device for the immense improvements which it received at his hands. Watt's work followed in natural sequence with that of Newcomen and Papin and Savery. And Savery's engine in turn was the reduction to practical form of an ancient scientific toy first described by Hero of Alexandria.

Of course, when we consider the use of the power in expanding gases we must not forget gunpowder, for it was in the use of gunpowder that we witness the first use of expanding gases. But as in the case of steam, in gunpowder also it remained for the West to develop its use. The Arabs knew gunpowder and the Chinese long before them but it was not until around the 12th or 13th century, A. D., in Europe that fire arms were developed on a practical scale. In 1326 a cannon was cast in Florence.

But to return to Hero, or Heron of Alexandria as he is also known. Hero was a Greek geometer and writer on mechanical and physical subjects who lived sometime between 150 B. C. and 250 A. D. In his *Pneumatica* among many other devices there is a description of a primitive reaction turbine, consisting of a hollow globe pivoted so that it can turn on a pair of central trunnions and supplied with steam through one of them which is hollow. The steam escapes from the globe to the outside air through two bent pipes facing tangentially in opposite directions at the ends of a diameter perpendicular to the axis. The globe revolves by reaction from the escaping steam. This, it is obvious, constitutes a simple reaction turbine.

In the light of present day knowledge it seems strange that, though these devices were described before or about the time of the beginning of the Christian era, there is no evidence to show that these devices were built or that any other application of the principles involved were made until another 15 or 16 centuries had passed. For it is not until 1601 in another treatise on Pneumatics by Giovanni Battista della Porta, that another device of a similar nature is described, and not until 1663 that a method of raising water by steam described by Edward Somerset, the second Marquis of Worcester, seems actually to have been made.

Between Hero and the Marquis of Worcester lie the middle ages—the dark ages as they are called, but this term is misleading. People take the term too literally and think of the middle ages as a period of darkness and stagnation, but this was altogether not so. As a matter of fact the people of those ages were as alive as we are and great states were founded. Large centers of commerce were being developed, cities and towns were developing, languages were evolving, religious philosophies were developing, and everywhere the world was in motion. Of course from our viewpoint progress during those ages seems slow but many of the foundation stones were being laid upon which later the beginnings of modern civilization were to arise.

Roger Bacon's Influence

In 1214 Roger Bacon was born and with him came the challenge to existing methods of thought. More than anyone else, this medieval monk deserves to be called the founder of modern science for he openly and passionately challenged the philosophies. He dared to suggest that an hour of actual observation was worth more than ten years with Aristotle. Naturally, in the face of the existing order at the time he was suppressed but his works remained to guide others who were possessed of similarly curious natures.

These matters, though somewhat irrelevant to the subject under consideration, nevertheless explain to some extent the reason for the lack of development in power producing technique between Hero and the Marquis of Worcester. Learning was confined to a few and most of the works of science and literature were written in Greek or Latin. It is significant that as soon as Hero's *Pneumatica* was translated into English about 1600, the Marquis of Worcester and Papin studied Hero's principles and by their experiments provided the basis for the engine of Watt.

A number of crude schemes and rude forms of apparatus, as those of Porta (1601), of Da Caus (1615), and of Branca (1629), were suggested by various ingenious philosophers and writers but the Marquis of Worcester and Papin, the distinguished contemporary physicist and philosopher, were the first of these schemers who seem actually to have constructed their apparatus. The Marquis of Worcester's apparatus was used for the purpose of raising water and consisted of a separate boiler delivering steam to two vessels filled with water and which are emptied alternately by the force of the steam.

From this time forward the minds of many men were at work on this problem—that of raising water by steam. This problem had become important in the mining of coal. Just when coal mining began we do not know but it probably began before the dawn of history. Progress in methods of mining, however, was very slow and until the 14th Century only the working of outcrops was followed. Then mining began, though until well into the 17th Century even the best pits were still only roughly timbered holes in the ground. The mines were often water logged and it was this problem of removing water and stimulated the early inventors of steam engines. By the end of the 17th Century English miners were beginning to find the greatest difficulty in clearing their shafts of the vast quantities of water which they had penetrated and it became a matter of vital importance to them to find a more powerful aid in their work than was then available.

The Idea of the Piston

So far, the idea of a piston seems not to have occurred to anybody but in 1690 Denys Papin constructed a working model of an engine consisting of a steam cylinder with a piston which was raised by steam pressure and which descended again when the condensation of the steam produced a vacuum beneath it. An actual engine was never built.

By the end of the 17th Century the idea of steam power had become quite common, though the first real steam power device for actual use in industry remained to be invented. This, however, was brought about by Savery in 1698 when he patented the design of the first engine ever actually employed in industry.

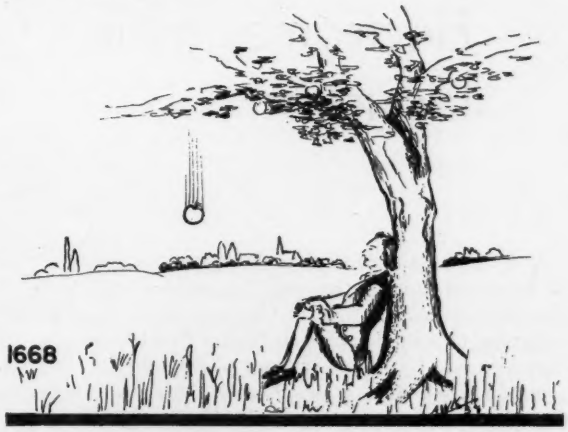
Savery's "fire engine" made use of a boiler supplying steam alternately to two oval vessels displacing the water in them and driving it out through check valves. When one of the vessels was emptied of its water the steam supply was stopped and the steam already there was condensed by allowing a jet of cold water from an overhead cistern to stream over the outer surface of the vessel. This produced a vacuum and caused a new supply of water to be sucked up through an inlet pipe. In the use of artificial means to condense the steam and in the application of the vacuum so produced as well as in other practical features, Savery's engine marked a great advance.

Before Savery's engine was replaced by its successor, Newcomen's, it was improved by J. T. Desaguliers and by Papin. While Papin was thus going back from his first motion of a piston engine to Savery's cruder type, a new inventor appeared who made the piston engine a practical success by separating the boiler from the cylinder and by using (as Savery had done) artificial means to condense the steam. This was Thomas Newcomen who in 1705 gave the steam engine the form shown in one of the drawings in these pages. Steam admitted from the boiler to the cylinder by the opening of a valve allowed the piston to be raised by a heavy counterpoise on the other side of the beam. Then the steam valve was shut and a jet of cold water entered the cylinder and condensed the steam. As a consequence of the vacuum so produced, the piston was forced down by the pressure of the atmosphere. The next entry of steam expelled the condensed water from the cylinder through an escape valve.

While Newcomen's engine had the great advantage over Savery's that the intensity of pressure in the pumps was not in any way limited by the pressure of steam, it shared with Savery's the defect that steam was wasted by the alternate heating and cooling of the vessel into which the steam was led.

It was this obvious waste of steam that attracted the attention of James Watt, an instrument maker in Glasgow, while he was repairing a model of Newcomen's engine and led him to suggest the remedy. He saw at once that this would lie in keeping the cylinder as hot as the steam that entered it. With this in view he added to the engine a new organ—namely, the "separate condenser"—an empty vessel separate from the cylinder into which the steam escaped after performing its useful work in the cylinder, and to be condensed there by a jet of cold water. To preserve the vacuum he added a pump called an air pump whose function it was to extract from the condenser the condensed steam as well as any air that might come in. After much experiment, Watt patented his improvements in 1769, thus laying the foundation upon which the later industrial era was to be raised.

It is not expedient here to discuss all the later improvements made upon the steam engine; of the work of Trevithick, Bull, Evans, Perkins, Hornblower and many others; of the development of the steam boiler from a mere kettle, through the fire tube, to the modern high pressure water tube boiler of today; of the invention of the steam turbine by Parsons and its evolution to the highly efficient units of our present world, but it will be evident, that once a method had been developed by James Watt and his predecessors, the rest followed inevitably. With Watt's engine, man's long preliminary groping was over. Much still remained to be done—indeed it was not until over half a century later that the thermodynamic principles underlying the steam engine were understood—but the way was clear and once man became aware of the enormous power at his disposal in expanding steam he was not slow in putting it to use.



One reason for the increase in scientific interest was Newton's discovery in 1668 of the law of gravitation

The Rise of Power

Electromagnetic Induction

AS INDICATED in the preceding discussion of the steam engine the early inventors had little to guide them in the way of theory. Watt had the advantage of a knowledge of Joseph Black's doctrine of latent heat; but there was no philosophy of the relation of work to heat until long after the inventions of Watt were complete. The theory of the steam engine as a heat engine may be said to date from 1824 when N. L. Sadi Carnot published a remarkable essay in which he showed that heat does work only by being let down from a higher to lower temperature. But Carnot was not then aware that any of the heat disappears in the process and it was not until the doctrine of the conservation of energy was established in 1843 by the experiments of James Prescott Joule that the theory of heat engines began a vigorous growth. From 1849 onwards the science of thermodynamics was developed with extraordinary rapidity by Rudolph Clausius, W. J. Macquorn Rankine and William Thomson (Lord Kelvin) and was applied, especially by Rankine, to the practical problems in the use of steam.

In the meantime, another form of engine using the energy of expanding gases had appeared—the internal combustion engine. The idea of the internal combustion engine had its origin in gunpowder cannon. Genghis Khan in China is recorded as first having used gunpowder in cannon about 1234 A. D. and in Western Europe its use for this purpose began about 1327. The earliest proposal to use the explosions of gunpowder to obtain continuous motive power was probably made by Christian Huygens in 1680 and Papin and Abbe Hautefenille later endeavored to develop his proposal but without success. Later it was found that gunpowder is entirely unsuitable for use in any internal combustion engine.

In 1794 R. Street proposed an engine driven by a flame-ignited explosive mixture of vaporized spirits of turpentine and air and this probably was the first real gas engine to be suggested. The commercial career of the gas engine began, however, with Samuel Brown in 1823 whose design operated on the atmosphere vacuum principle.

Thus, by the second quarter of the 19th Century, the evolution of two forms of engines was in progress and many applications of them were made in transportation and industry. The introduction of the steam engine in the factory was the real beginning of what we now call the "industrial revolution."

In the meantime other things were happening. As early as 600 B. C. Thales of Miletus, whom we have already mentioned, had noticed that amber after being rubbed attracted bits of straw and feathers. These attractions were again studied by William Gilbert in the 16th Century and he called such attractions *electric* after the Greek word meaning amber. These studies resulted in the development of strange machines by means of which electric sparks could be produced and which were exhibited in the drawing rooms of genteel society. Now there was little about these parlor tricks to suggest anything of very fundamental importance. The fact that if a rod is rubbed with the skin of a cat it will pick up bits of paper would not seem to have in it anything of a revolutionary nature, in fact one can hardly imagine a set of phenomena more vulnerable to the scoffer, for rods and cats have been the stock paraphernalia of witches from time immemorial, and blue light visible in the dark adds no particular prestige to the phenomena. Yet towards the end of the 16th Century these things were much in men's minds.

About this time also the strange power of the magnet came under increased observation and many attempts were made to make perpetual motion with

the aid of magnets. There was, in short, an increase in the scientific temper and certain individuals throughout Europe were experimenting with various things. One reason for this great increase in scientific interest in experimental methods was Newton's discovery in 1668 of the law of gravitation. In his great "Principia" he had demonstrated the powerful implicities of the fundamentals which control the destinies of the heavens. No longer did the universe appear a bizarre and formless thing governed by a heterogeneous system of agencies. In one simple law—that of a force emanating from the sun according to the inverse square of the distance therefrom —Isaac Newton had explained all these things. All mystery had been cleared up. The universe was orderly and nature's secrets could be explained.

The Discovery of Current Electricity

Often experiments in one field lead to discoveries in entirely different fields. In 1780 Luigi Galvani, a professor of physiology at Balogna in Italy, in studying the anatomy of frogs accidentally discovered what was later to be known as "current" electricity to differentiate it from the static charges produced by the static machines and thus laid down the basis for Volta's work later on. Alessandro Volta in 1800 discovered the method for producing electric currents of appreciable magnitude by means of chemical action. For the first time an electric current was sent through conductors. Very shortly after Volta's invention of the voltaic pile it was discovered that a bright light was produced at a break in the circuit of a sufficiently powerful pile, and in 1809 Sir Humphrey Davy showed at the Royal Institution in London the brilliant light of the voltaic arc which he established between two sticks of carbon with a pile formed of 2000 couples. Strictly speaking this was not the first arc light since the sparks produced between the poles of static machines were also arc lights, but it was the first time the possibilities of such a light for practical use was demonstrated. Before that, however, in 1785, A. C. Coulomb had carried out his classical investigations and discovered the inverse square law of force between magnetic poles.

The next important step was the discovery of the relation between magnetism and electricity. In 1819 Hans Christian Oersted found that a magnetic needle placed parallel to a current carrying conductor tended to set itself at right angles to the current. This discovery was followed rapidly by other investigations and in 1820 Andre Marie Ampere showed experimentally the mutual action of current-bearing circuits. In the same year Arago succeeded in magnetizing a piece of iron by an electric current and shortly afterwards the whole subject of the mutual action of currents and magnets was dealt with comprehensively by Ampere in one of the most celebrated memoirs in the history of physics.

Developments, it is seen, were coming thick and fast. The strange force of electricity had intrigued men's minds throughout the world. In America, in 1752 Benjamin Franklin had established the identity between atmospheric electricity and ordinary electricity by his celebrated kite experiment. In 1826 George Simon Ohm published a paper on the flow of electricity through conducting wires in which a result since known as Ohms law was established.

No investigation or discovery equaled in importance nor led to such far reaching consequences, however, as the one made on August 30, 1831, by Michael Faraday, in his discovery of electromagnetic induction. And nobody was more fitted or better equipped to make this discovery, for in no more than ten full days of research between August and November, this master of method and observation unraveled all the essential features of electromagnetic induction and produced the world's first electric generator. The discovery of electromagnetic induction ranks probably as the most important single discovery ever made, the effect of that discovery revolutionized our entire civilization in making possible the electrical transmission of energy.

Yet, it was a long way from Faraday's discovery of electromagnetic induction in August of 1831 to the opening of Pearl St. Station in New York in 1882 which was the world's first central station. In that half century all the loose threads had to be picked up, sorted, and woven into the fabric of our present day civilization.

In 1831 the steam engine was still in a crude state—it would be years before it could be developed into a device suitable to drive even the crude Jumbo dynamos of Pearl Street Station. Thomas Edison was not to be born for another 16 yr. The internal combustion engine as has already been pointed out had scarcely been born. John Fitch, Robert Fulton and others had applied the steam engine to ships and Stephenson in England had built a successful locomotive but seven years would have to elapse before the first steamship, the Sirius, would cross the Atlantic. There was not an electric motor in the world and it would be four years before Morse would invent the telegraph. The McCormick reaper was still four years away, and nobody in 1831 had ever seen a photograph.

Joule, Maxwell and Hertz

But the beginnings were all there and the next century was to witness the most remarkable advance the world had ever seen. More was to be accomplished in that one century in the way of scientific development than had been accomplished in all the countless thousands of years before. Faraday was to continue his brilliant work, first in enunciating the laws of electrolysis, thus laying the foundation for the art of electro-chemistry and later in 1854 in establishing the relation between optics and electricity and magnetism.

As already mentioned in connection with the development of the steam engine, the principle of the conservation of energy had been discovered by Joule and around 1843 he finally placed it upon a solid basis by applying it to electric circuits. Lord Kelvin between 1847 and 1853 worked out the theory of energy of electromagnetic systems and followed this with the theory of the oscillatory discharge.

About that same time (1855) James Clerk Maxwell began his study of electromagnetic phenomena

which resulted in his discovery of the electromagnetic theory of electric waves and light, the theory which is of fundamental importance in all branches of modern physics and which led to Hertz' experimental discovery of electric waves and this in turn providing the basis on which the entire present day art of radio is founded.

While these developments in electricity were in progress, the continued perfection of the steam engine and its increasing application was bringing about what has now come to be known as the "industrial revolution." In the use of this term, "industrial revolution," we have in mind a definite picture of life and power—of a picture which contrasts the difference between two societies, one which is based upon a very simple agricultural, hand-labor order and the other making great use of machinery and which supplies the needs of its simplest members by an eleborate series of world wide exchanges. In other words, by the industrial revolution we mean the change that transformed a people with peasant occupations and local markets into an industrial society, using great power and machines, with world-wide connections.

It is impossible in a general discussion such as this to refer in detail or even enumerate all the new inventions and new uses of power which transpired during this period during the latter quarter of the 19th and the first half or three-quarters of the 20th century. All the threads of development and invention were being drawn together into the fabric of the new "machine age." Each new machine furnished ideas for other new ones; the need for large quantities of metals and fuel developed the mining industry and the need for transporting materials brought forth improved methods in transportation. Railroads and steamship lines multiplied. The invention of the telegraph speeded communication and men began to think of spanning the Atlantic with a cable. The rotary printing press was developed by Hoe in 1847, the turret lathe came into being and the beginnings of our highly complex machine tool industry was started. A thousand and one other machines and devices were created.

But all of them were the result more or less of the great increase in available energy brought about by the development of the steam engine. It is not the purpose of this particular article to discuss the social and economic implications of this new order in human society but they were far reaching. Great industrial centers arose, labor and housing problems developed, the need for increased capital brought about complexities in banking and credit exchange which multiplied as the entire system became more complex. The machine uprooted old traditions and relations. Social and economic forces underwent rapid alterations as a result of the more fundamental and productive force of the machine. Periods of prosperity and depression followed one another in rapid succession. The suffering and discontent of the great masses of people who represented the workers during this transition period are a matter of history of which we can have no reason to be proud.

The Rise of Power

The Electrical Transmission of Energy

NOW we come to another important date in the history of man's rise in the use of power. This was September 4, 1882, when Thomas Edison's Pearl Street Station was first started, supplying electric power for lighting incandescent lamps to a territory covering about one square mile in downtown New York City. This was the culmination of years of experimentation and development on the part of Edison and others, and marked the beginning of still a new order in human affairs—the power age; the age of the electrical transmission and distribution of energy.

The reason we speak of the power age in contradistinction to the machine age which, as we have seen, was ushered in by the advent of the steam engine, is because of the very fundamental difference brought about by the electrical transmission of power in the pattern of our civilization. These fundamental differences are discussed in detail in other sections of this issue, but to put it briefly here, this difference amounted to the emancipation of the machine from the prime mover. Before the electrical transmission of power it was necessary to couple the machine—textile, paper, machine tool, etc.,—directly to the prime mover by means of belts, gears, or shafts. This meant that the centers of industry necessarily had to be located at the sources of power.

With the advent of electric transmission this was no longer necessary; a factory could be placed anywhere and power could be transmitted to it by electric transmission lines; towns and cities could be located remote from the centers of production, and of even greater significance perhaps, relatively large amounts of power could be brought directly into the homes of individuals to contribute to their comfort and relieve them of drudgery.

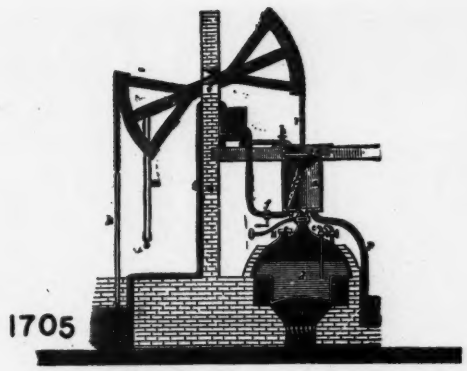
The opening of Pearl Street Station in 1882 was therefore an event of outstanding importance for that was the beginning of this new era of electric transmission. Before that the arc light first demonstrated by Davy, had been perfected and by 1866 sufficiently powerful and efficient dynamos were built to allow the installation of arc lights in a few lighthouses in France and England and during the seventies are arc light gradually grew into a commercial device satisfactory for the illumination of streets and large auditoriums.

About the same time the electric motor began to develop. As early as 1821 Faraday had been able to make a pendulum-like wire swing around the pole of a magnet whenever current flowed in the wire. This was the first electric motor. After Faraday's discovery of the dynamo, the motor was developed in the hands

of Siemens, Gramme, Eickemeyer, Davenport and others and it was already a highly developed machine when Edison began his work. In the meantime also various attempts had been made to produce an incandescent electric lamp but none of these were successful until Edison produced his first lamp in October, 1879.

And so ends our story of the rise of power. The rest, that is what happened between opening Pearl Street Station and today, is common knowledge. Of the tremendous period of development in the generation and distribution of power, of its increasing application in transportation, communication, industry and household activities, little need be said here. Once the way was shown the rest followed inevitably. The development of the steam turbine in the hands of Parsons, Curtis and others solved the last problem in meeting the ever increasing demand for power, until now units of 160,000 and even 200,000 kw. are in everyday service. Little has been said here of the rise in transportation and communication; of the development of the internal combustion engine into the highly efficient gasoline and Diesel engines of today which drive automobiles at over 300 miles an hour and enable airplanes to cross the Atlantic, in a matter of hours; of the marvelous consequences of Hertz' researches on electric waves in the development of our world wide radio, telephone and telegraph systems, of picture transmission; of the talking colored motion picture and television. Nothing has been said of the development of the electron theory, of its great unifying influence in te realm of physics, chemistry and electricity; of the great research laboratories in our manufacturing plants, colleges and government bureaus. And no mention has been made of our great chemical industries, of the production of synthetic plastics, fabrics, perfumes, dyes and countless thousands of wonderful and valuable products, nor of the production of aluminum and metallic alloys. A discussion of each would fill volumes.

But all of these things are directly or indirectly the consequences of a power age, of a tremendous increase in the availability and use of external power. Power has brought its problems but it has inherent in it the possibility of freeing man forever from all the drudgery and discomfort which have characterized all by-gone ages. The use of external power has made



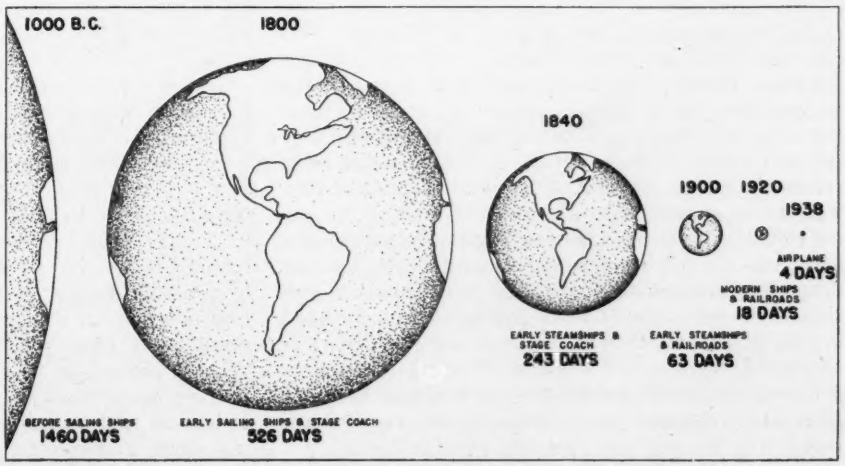
Thomas Newcomen's Engine in 1705

the world smaller. In communication the most remote corner of the world is as near as our telephone; in transportation London is a half day from New York. The use of external power has brought us from an energy level of a half horsepower per capita to one of 5, 10, 50 and even 100 horsepower per capita.

What the future will bring, nobody knows, but this much is certain—if we can solve our non-power problems—the problems of adjusting ourselves to changing environment brought about by the increased availibility of energy, technical progress will continue to make this a better, more comfortable, safer and happier world. But if we do not solve these non-power problems, if we do not use this new power intelligently, its misuse can be as destructive to our continued existence upon this planet as its wise use can be constructive. It all depends upon us. The social and economic problems which confront us today as a consequence of the increase in available energy are due not to any inherent fault in the use of power itself but to our lack of understanding and inability to cope with the sudden acquisition of so great a force. Too few of the people in the world understand what is going on. In the words of the greatest thinker of our age, Albert Einstein, our troubles "are due to the fact that the intelligence and character of the masses are incomparably lower than the intelligence and character of the few who produce something valuable for the community."

The World Has Become Smaller

In terms of transportation and communication the world has become smaller rapidly. As is shown by this diagram with each new discovery it has dwindled in size, until now by means of the airplane it can be encircled in 4 days. This diagram is based on the earth's circumference at the 42nd degree of latitude. In terms of communication, the earth has practically vanished since all parts of it can be reached instantaneously.



MAN

Photo, Courtesy Westinghouse

FOR OVER a century the dominant theme in the symphony of our developing industry and civilization has been the song of the machine. The hum of its power-driven wheels has been accepted as a sign of progress toward a higher standard of living—a better, freer, fuller life. The construction of bigger and more powerful machines has been taken to represent the increasing domination of man over forces by which he was enslaved in the pre-Machine Age.

The harmony of this main theme has been disturbed by discordant notes of criticism from those who fear the final outcome of man's glorification of the machine. Ground for this pessimism is found in the tremendous transformation which the power-machine has brought in the character of man's daily work. "I watched a man," writes one critic, "shove metal rings across six inches of space to a guide from which they were taken automatically through the machine, emerging slotted some seconds later, without more human ado. That was his job from morning until night, his pay depending upon how many slotted rings passed inspection. Eyes concentrated on his little platform, one hand moving thus, the other so, in unending repetition: he missed not only one revolution of the wheels which were grinding out his life, even as they ground out the goods. Economically he was part of the machine—an automatic feeder who chanced to be flesh-and-blood and mind."[1]

Such tasks, it is said, multiplied in modern industry by the availability of cheap power for operating machines, has actually made man the servant of the machine. The machine, by destroying handicraft, has taken from the worker a means of self-expression. By the substitution of machine tending and feeding for individual crafts, it has condemned the mechanically gifted and skilled worker to a life of perpetual maladjustment. Above all, it is claimed, relentless mechanization has condemned man to the unending monotony of repetitive work which dulls the mind and thwarts the instinct of workmanship and allied creative and aesthetic impulses.

Such are the pessimistic observations by critics of our industrial civilization. However, these generalizations, when examined, appear to grow out of the free play of poetic imagination rather than from controlled and scientific study of the industrial situation. Such studies, by psychologists here and abroad, show clearly that much of the blame levelled against work with machines is wrongly directed. They indicate, for example, that machine work, repetitive work at an imposed speed and rhythm, is not invariably accompanied by an overwhelming and depressing feeling of monotony. There seems to be no universal, deep-seated conflict with an instinct of workmanship. As a matter of fact, there are many who prefer routine work, who like automatized tasks which leave the mind free for other pleasurable activities. There are others, apparently a smaller number, who rebel against uniform, specialized work, but even in their case, adaptation is not so difficult as it is suggested by the protagonists of the "creative" instinct.

To the extent that monotony does become a disturbing factor, its unfavorable effects can be reduced by relatively simple techniques. Proper vocational selection is a step in the right direction, since it helps to shunt away from repetitive tasks those who are adversely affected by it. The substitution of varied for uniform work is not altogether an impractical solution, at least in some cases, since the introduction of variety into work often reduces the feeling of boredom without

AND THE MACHINE

BY MORRIS S. VITELES, Ph.D.

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interfering with productive efficiency. Incentive wage plans, rest pauses, other alterations of working conditions, the arousal of indirect interests in the task, etc. can further contribute to overcoming excessive monotony in work.

In general, the most encouraging aspect of psychological studies is their failure to confirm the point of view that the human mind is dulled, emotional maladjustment seriously intensified, or broader social participation hindered by repetitive work. In these respects, the findings of experimental investigation coincide with what is shown by a review of the history of work. Throughout the ages a large proportion of workers has been accustomed to some form of repetitive work. Long before the appearance of machines many tasks had already become highly standardized and routine in character. The hours and hours of polishing required for the preparation of flint arrowheads used by the primitive tribes must have been extremely monotonous work. Hand weaving, with the repeated throw of the shuttle from side to side, has in it all of the elements of repetitive work of the Machine Age. Moreover, the long hours devoted to work left little, if any time, for recovery from its ill effects.

Not so many years ago, for unskilled and skilled workers alike, the working day started at gray dawn and continued until dusk. Today, as William Green, President of the American Federation of Labor, has picturesquely phrased it, "bankers' hours have come into industry." The short work day and week represents a privilege never enjoyed by workers before the present century. In 1815, cotton mills, for example, were generally run on single shifts of 14 to 16 hr. per day, frequently for 7 full days each week. These hours applied even to 8 and 10 yr. old children whose noon-rest of half an hour was hardly longer than that enjoyed by the peasants of the Middle Ages. In 1860, hours of labor still averaged 66 per week. In 1887, they had dropped to 60 and by 1907 to 57 hours. At present, in part because of the discovery that production generally does not suffer from a reasonable curtailment of working hours, these have been widely reduced to 48 and 44 hr. and even, in some industries to 36 and 32 while, under the Federal Fair Labor Standards Act, the maximum work hours at standard wage rates are legally reduced to 44 per week.

The shorter working day and week, the higher standards of living, facilities for employe education and recreation available to the worker in the Machine Age combine to give the worker opportunities for relaxation, self-expression and creative experiences outside of working hours beyond the scope of anything that existed in earlier ages. The problem appears to be largely one of encouraging and educating workers to take advantage of these opportunities. Its solution may involve an attempt to substitute more productive and creative experiences for the automobile ride, the baseball game, the movies, the radio, which at present seem to occupy the spare time and mind of the American worker. It is to the development of a program to stimulate such substitution, rather than to the critique of mechanization in industry, that the attention of the social reformer should be directed. And if, in spite of education for the use of leisure, most men and women continue to find adequate satisfaction in the simpler and less creative forms of relaxation, this in itself may be evidence that creative experience is something which today, as in the past, is craved by only a few selected spirits.

Although such facts concerning the effect of repetitive work and shorter hours in industry are encouraging, they should not blind us to the need for further advances in reducing fatigue, overcoming the effects of monotony, and in otherwise promoting the continued adjustment of the worker in modern industry. In the first place, many plants, quick to adopt mechanical and operating improvements, are still backward in applying psychological and allied techniques designed to promote the well-being of the worker. Criticism directed against the Machine Age only too frequently finds support in the personnel practices of individual plants which are the relics of an earlier and less happy era in industrial management.

In addition, much research remains to be done in further facilitating the most *economical* and *healthful* use of human energy in industry. So, for example, there is evidence which shows that work with machines

In 1752 in America Benjamin Franklin proved the relationship between lightning and electricity

and moving belts, in spite of increased speed, is made easier by the regular and rhythmic character of activity as contrasted with the irregular and sporadic nature of movement when the tempo is under the control of the worker. However, other investigations show that the efficiency of working on practically every task, that is, the ratio of the work done to the energy expended in doing it, rises up to a certain speed and falls off again.

For every type of work there exists an optional speed and rythm which makes it possible to obtain maximum production with the least expenditure of energy and without increasing the feeling of fatigue, discomfort, and ill health. The determination of those speeds and rythms which are optimal from the point of view of human efficiency is an almost untouched field. They have been fixed again and again, for many types of work, with respect to highest rate or amount of production. There is reason to believe that this rate often conflicts with the welfare of the worker. The effect of variations of speed and rhythm upon fitness represents a fertile field for further investigation with the view of further preserving the well-being of the worker while taking full advantage of the productive capacities of the power-machine.

As indicated earlier in this discussion, among the accusations levelled at power driven machinery is that it has decreased the demand for skill in industry by destroying handicrafts. The specialized jobs on the automobile assembly line are repeatedly cited as proof that workers have been reduced to the status of machine feeders and machine tenders requiring little of the manual proficiency demanded, for example, of the carriage makers of earlier days.

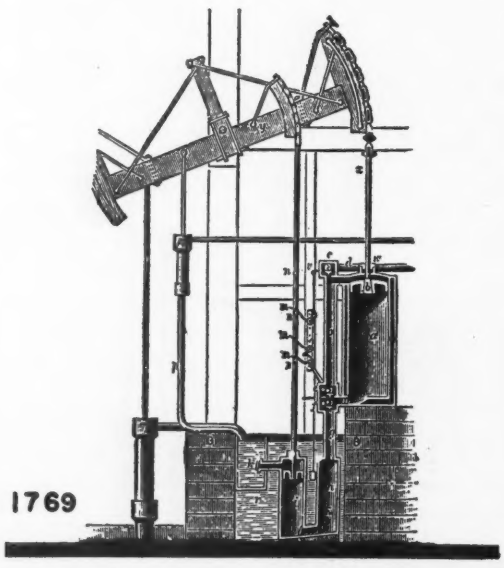
Actually, in many industries, changes in skill requirements have been far from marked. Printing, for instance, was rated as one of the most skilled forms of work even during the Handicraft Era. At present, the extent of mechanization in it is duplicated only in the spinning and weaving trades. In the past century output per man has increased from a few hundred impresses a day on a hand-press to as many as 500 per minute on a machine attended by 4 or 5 pressmen. Between 1914 and 1929 the number of workers employed in book and job printing rose from 113,121 to 150,649—an increase of approximately 33 per cent. And still, in a comprehensive study of the commercial printing industry by Professor Baker, of Columbia University, nothing was found to support the point of view that skill suffered from the introduction of the machine into this industry.[2]

On the contrary, the evidence shows clearly that although old hand skills are transferred to the machine, new and more elaborate skills must be acquired as the machines grow in size and complexity. In the printing plant, for example, the pressman is a skilled worker. The work of the assistant, who feeds paper by hand or acts as a pressman's helper, is much less skilled. In 53 New York plants, over a period of 5 yr. (1924-1929) the employment of pressmen increased 8 per cent while that of assistants decreased 6 per cent. In other words, technological advances in the commercial printing industry affected relatively unskilled handfeeders more than the skilled pressmen.

Such figures show that skill—more particularly manual skill—still has an extremely important place in modern industry. There are, it is true, industries in which the demand for skill has declined at a greater rate than in the field of commercial printing. So, in the automobile industry, between the years 1910 and 1930, while the total number of workers increased from approximately 105,000 to 460,000, the proportion of skilled workers declined 11.9 per cent—from 45.7 to 33.8 per cent. However, in many industries the rate of decrease is more gradual than would have been expected.

In general, technical skill and technical knowledge of a high order are still required for the construction, maintenance, repair, and adjustment of the marvellously intricate and deft machines that perform much of the handwork formerly done by man. The "iron man" has created for his own making a need for workmanship and special knowledge unknown to the ages of simple, primitive tools; it has called for the development of new skills for the production of new machines, new operations, and new processes.

As is pointed out in a recent report on "Technological Trends and National Policy," machines and power have definitely created more callings and more employment than they have eliminated. Aided by science and engineering they have "been responsible for the creation during the past 70 yr., where nothing was before, of such giant industries as those which manufacture automobiles, radios, typewriters, talking machines, airplanes, electric refrigerators, air-conditioning equipment and telephones, as well as new utilities which are concerned with electric communication, electric transportation, and electric light and power."[3] These have added new opportunities for profitable employment and happy careers for millions of skilled workers as well as for machine feeders and tenders.



James Watt, basing his work on the previously designed engines of Savery and Newcomen, in 1769 produced the first efficient steam engine

[2]E. F. Baker, "Displacement of Man by Machines," Columbia University Press, 1933, 284 pages.

[3]A. A. Potter and M. M. Samuels, Section V, Power,—Technological Trends and National Policy, National Resources Committee—75th Congress, 1st Session House Doc. No. 360, June, 1937, p. 264.

In spite of the tremendous multiplication of labor opportunities—resulting in part, from mechanization, the availability of cheap power, and technical progress—there is a tendency today to take a gloomy view with respect to the extent of displacement and permanent unemployment which will result from changes now taking place which have the effect of decreasing labor requirements per unit of production and thereby reducing the volume of employment. It may well be that this represents a permanent trend which calls for serious industrial, economic and social readjustments. On the other hand, we may be faced merely with a revival of protests and discussions concerning the introduction of new machines which have characterized every period of widespread unemployment. It is still very likely, to quote from an English authority, that "the old economic argument which sought to prove that technical progress serves in the long run to expand rather than to contract the demand for labor is still valid."[4]

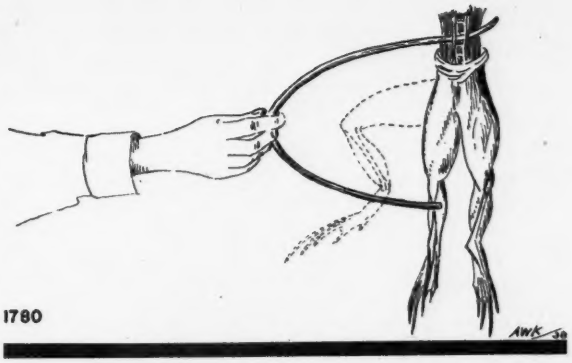
Under any circumstances, displacement by technological changes in machines and processes presents a fearful problem to the worker involved in the displacement, regardless of what the "long-run" effect may be on something vaguely known to him as society or civilization. To promote the readjustment of the individual who becomes so involved represents a practical problem to which industry and other social agencies may profitably direct attention. So, for example, industry can facilitate the transfer of its own workers to new jobs, demanding new skills, by providing training opportunities to experienced employes.

The application of this policy may mean, for example, that in the printing industry hand-feeders will be taught automatic press operation prior to the installation of new machines. In the electric industry d.c. station operators will be taught the principles and practices of a.c. operation as a step in adjustment to prospective change-over from one to another. Employes in traditional coke gas-making plants will become acquainted with the reformed oil process, in preparation for the day when a shift in operating practice may be found necessary, etc. That this is a practical program has been demonstrated in the work of a number of organizations, such as the Philadelphia Electric Co.

Not alone industry, but other agencies, in particular the public vocational schools, have a responsibility in this direction. Many such schools are still training men for trades which are quickly disappearing or have been completely transformed in recent years. The program of vocational education in the schools is in need of reorganization, so that training may cover the exact processes now employed as well as trades or jobs in the process of development. Moreover, to help the workers in those industries where highly skilled trades are being rapidly replaced by less skilled machine tending and feeding and assembly jobs, provisions should be made for training which will furnish a certain proportion of young people with a set of fundamental skills that can be used in many jobs, thereby providing for quick adaptation to rapidly changing forms of work.

The complete realization of this program calls for further study and investigation to make available more facts on occupational trends, more detailed knowledge

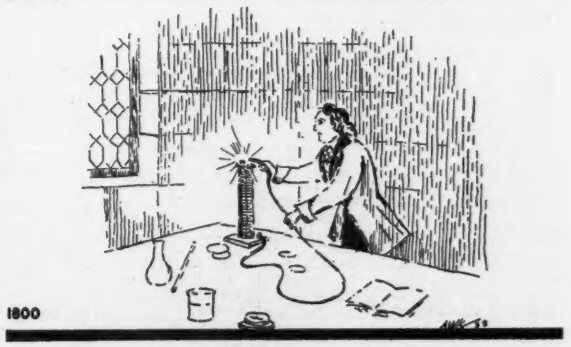
[4]H. D. Henderson, "The Displacement of Labour by Machinery," The Human Factor, 1937, p. 253.



Discoveries in electricity were accelerating. In 1780, Galvani discovered current electricity

of the nature of skill, improved methods of vocational training and re-education and better planning. When such facts on occupational trends are available, when basic questions on the nature of skill are answered, when ordered planning becomes an established practice, progressive training of men for new forms of work, through vocational schools and other agencies, will undoubtedly be one of the most important devices for preventing and overcoming many of the adverse effects of displacement of the individual.

As has been said in the introduction to this article, it is fashionable at the present time to blame the power-machine for many of the so-called evils of the age. Actually, in spite of its abuse, the power-machine has brought improvements in conditions of work and standards of living that have completely revolutionized the Western World. To place upon it the blame for the evils of our age is an easy way of escape which overlooks the real issue at the bottom of our problem. This is the failure of mankind to apply strictly the simple truth that "we tend to a mechanically perfect society in which we will either master the machine or be enslaved by it." The road to mastery is a complete understanding of the interplay of human and mechanical forces in the complex industrial civilization created by power machines. To arrive at such an understanding, with the aim of promoting by systematic, scientific methods, a more effective application of human energy in occupational life and a correspondingly higher standard of comfort and welfare for the workers is the task to which psychologists, engineers and other scientific groups must continue to devote themselves.



As a consequence of Galvani's discovery Volta in 1800 invented the voltaic pile.

Radiating from the modern factory power plant come those services that relieve fatigue, provide healthful surroundings, run heavy machinery, supply process heat and pressure needs, and speed up production

Power In Industry

IT WAS not until the industrial revolution in Great Britain that the civilized peoples of the world began to recognize that the application of mechanical power to industry meant both a definite step forward in the standard of living, advantageous to the welfare of nations, and a distinct change in the occupation of peoples who toil with their hands to produce, from the materials gathered from mines, fields, forests, and the seas, the things needed by men to house themselves in the comforts of the day, to clothe themselves according to prevailing fashions, to feed themselves as required for sustaining their physical health and to provide transportation to carry on the needed commerce of the time. It was when workmen began to realize that the physical labors of their bodies could very effectively be replaced by power derived from fuel, falling water and wind, and they began to experience the competition set up by machinery and specialized production, that the first real opposition to the use of machinery developed as a social problem.

The experiences of the workmen and manufacturers of that day are still reverberating today in the industrial life of the world. Every now and then new products of scientific laboratories are worked into commercially applicable tools or machinery that will replace the services of numerous workmen or require them to learn new trades.

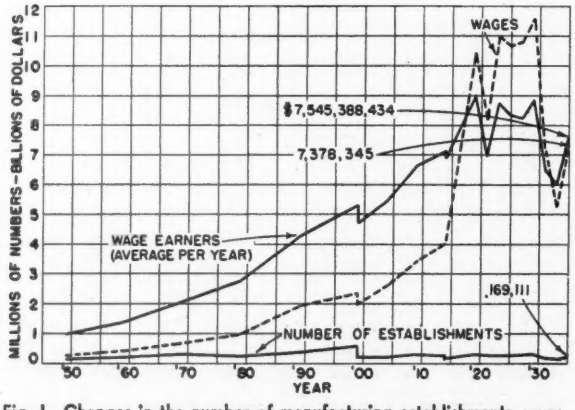


Fig. 1. Changes in the number of manufacturing establishments, wage earners and wages paid

Human Needs Supersede Capital Desires

Through this entire period since the beginning of industrial revolution, the strife between employers and employes has frequently been fanned into economic and social controversies that have occasionally resulted in virtual warfare. In all major crises in civilized countries, however, the cause of humanity has always prevailed against the use of capital for exploitation purposes and in America today the general standard of living is far superior to conditions as they existed at the turn of the century and are surpassed by no other country at the present time, due in large part to the extensive use of power derived from inanimate sources to drive machinery in the manufacture of products needed or desired by society.

Up to the time when machinery came into common use in industry, the ambitious workman labored in the hope of establishing himself in business where he could, with the aid of apprentices and skilled artisans, supply the trade with products of his shop at a profit sufficient to place himself on an economic plane comparable at least with the middle classes of other occupations. Machinery, however, that was being installed to be run by powerful water wheels and steam engines, and would replace much of the manual labor then used in factories, demanded such great outlays of money that even the best of artisans could rarely hope, through the savings from their labors, to establish themselves as individual owners of manufacturing plants.

Thus was born the need for companies and cor-

Photo, Industrial Rayon Corp.

porations in which workmen's financial savings were pooled and manufacturing establishments began to grow from camparatively small beginnings to firms of vast size and importance. This change has been taking place gradually ever since Watt's time and even today many of our best manufactured products come from shops owned by individual artisans who have established and operate their own business concerns.

Be it said, however, that through all the controversies between employers and employes, the use of power driven machinery of the labor saving type has been steadily increasing in factories since the early days of the industrial revolution in spite of determined and occasionally bitter opposition. Each period of depression has developed a crop of sociologists who attribute the major cause of that particular depression to the extensive use of labor saving machinery, yet on every occasion when other sociological conditions have been adjusted, prosperity has returned without any record in history of a prolonged retreat in the progressive use of labor saving machinery.

The industrial revolution, i. e., that sociological change which occurred during the period in the industrial history of the human race when ownership of manufacturing establishments was passing out of the hands of the individual working artisan into the control of financially wealthy persons or combinations of capital accumulated from workmen's savings, has placed less and less value on the services of the human drudge and in his stead industry is using a larger proportion of the more intelligent workers who are required to use judgment and scientific skill in the control of power driven machinery. Through this period has come the great and universal demand for education particularly in the applied sciences.

Out of this forced necessity for education has come the engineering professions as we know them today and through them the power age has progressed unabated despite all opposition of resisting human forces. And as the power age has progressed over long periods of normal business activity, the manufacturing industry has continued, except during recognized periods of social disturbances, to place more men at work at higher wages with shorter hours of labor under vastly improved working surroundings and better home environment.

Census of Manufacturers

To indicate the trends of progress, attention is directed to the United States Census of Manufacturers. Unfortunately, the printed reports of "Horsepower (rated capacity) of Power Equipment," are given for the rather short period of time from 1899 to 1929; other data, however, are available from 1849 to 1935 with the last census in 1937 being compiled at the time of this writing. Averages and totals do not, of course, map the direction for individual cases; they are, however, the best known basis upon which to formulate future plans.

Until the electric motor was put into commercial use, the application of power from the prime movers to manufacturing machinery was of necessity through mechanical transmission. This method had a definitely limiting effect upon the application of power for the mechanical losses encountered in transmitting to distant parts of a factory precluded the use of power for many machines requiring only fractional horsepowers and it was not until in the 1880's that a definitely marked increase in the application of power to the numerous small machines began to take place in factories. It was also about this time that the central electric generating stations put in their appearance and inaugurated an entirely new industry, serving not only factories but small shops, residences

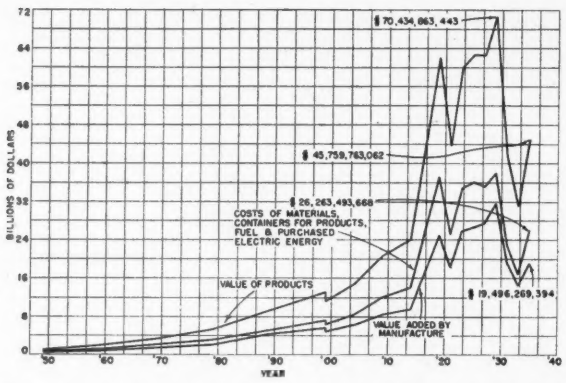


Fig. 2. Variation in the value of products, costs of materials and value added by manufacture

and even farms miles distant from the generating stations.

Beginning this study of manufacturers' statistics with 1849, the first year for which authentic data for the United States are available, curves are presented here which pertain to the influence of power on the manufacturing industry. All these curves point to a decided increase in the manufacturing industry over the long range of years. Abnormal conditions have existed at several periods during the past 80 odd years covered by these curves, some of which, due to infrequency of the censuses, do not reveal themselves in the curves, but as these conditions straightened themselves out the curves are, in general, smooth with an upward trend until the outbreak of the World War in 1914. From that time on to the present, fluctuations in most of the curves have been wide and irregular, but the long range trend is still on the increase so far as quantities are concerned. During the Civil War period, there can be little question that the value of products, wage earners and wages paid fluctuated sharply, but this does not show, due to the 10-yr. gap in census figures. Other disturbances occurred in the '70's following the panic of '72, in the early '90's and again in 1907, none of which are indicated by these statistics, but with normal conditions restored the upward trend has been continuous.

Starting with 123,025 manufacturing establishments in 1849, each having an annual output valued at more than $500, by '69 the number was more than doubled to 252,148, remaining almost constant during the next decade, but jumping 40 per cent in the '80's to 355,405 in '89 and another 44 per cent at the next census year '99, or 512,191. At this time the basis was changed to exclude hand and neighborhood industries which brought the number down to 207,514. Another change in basis was made in 1914 when reports made are for those establishments with annual products valued at more than $5,000, and again in 1933 about 1200 railroad shops were excluded. Thus we find that in 1914, 177,110 establishments increased to a peak of 214,383, receded and came back to 210,959 in 1929, with another decline and upturn to 169,111 in 1935. While summarized figures are not available for 1937, the indications are that little change has been made.

It is interesting to note that in 1899, when the hand and neighborhood industries were dropped, they numbered nearly 300,000, with about 600,000 wage earners, or an average of two to each establishment, the annual wages of each amounted to $520. In the larger plants the average wage came to only $426 per year, but the 1935 census shows wages averaged $1018 in the manufacturing industries.

The curve showing the average number of wage earners for the year starts in 1849 with 957,025, the dip at 1899 was due to the dropping of the hand and neighborhood industries. The peak reached in 1919 probably was not the highest, since that was the year following the close of the World War, when production had begun to slow up. The dip in 1921 was soon passed and a rather steady high-level normal of employment continued from 1923 to '29, since which time employment has been severely low with an upturn in 1935 which continued through 1937.

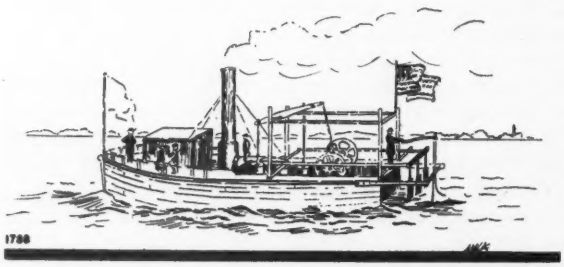
Wages paid to factory employes as indicated by the curve follow the same general trends as the number of employes, but the curves, plotted to different scales, cross each other at points where the average earnings per employe are $1000 per year. The average earnings as reported reached the peak in 1919 at $1162.

Cost of materials, containers for products, fuel, and purchased electric energy have, as a general trend, increased more rapidly than sums paid out for wages. The peak was reached in 1929, exceeding the 1919 figure, the previous high point.

Value of products followed trends similar to material costs, not quite parallel, but the ratios are fairly constant. It is interesting to note that at the turn of the century the average value of product per wage earner was $2440, while at the peak in 1929 it was $8000, and in 1935 it amounted to $6200. This difference in earning value of employes is definitely traceable to the amount of power used in factories, as is indicated by the curve of horsepower capacity of installed generating equipment and motors using purchased electric energy.

Value added by manufacture increased but slightly over the wages paid during the first 30 yr. covered by the available data. At this point, 1879, the electric motor was beginning to be used and its effect on the value added by manufacture seems clearly indicated by the rising curve.

Curves for the horsepower (rated capacity) of power equipment in manufacturing industries are enlightening, although unfortunately they do not



Just before 1800, steam power was being applied to ships. This is John Fitch's steamboat in 1788

extend over a sufficiently long period to make comparisons with earlier uses of power. From history, however, it is known that during the period since 1900 the greatest advances have been made in the application of mechanical power to factory production that industry has experienced. Prior to that time, factories depended principally upon mechanical drive, the electric motor, being only a generation old, had many serious disadvantages to overcome, but by 1900 the motor was well on its way towards general application to power driven machinery, and electric generating equipment was installed in nearly all factory plants that did not depend upon electric utility service.

It was also about this time that central stations had made long distance transmission of power commercially successful and it will be noted that the capacity of motors run by purchased power was almost insignificant in 1899, but made continuous gains until in 1927 it practically equaled that of the prime movers in factory plants and actually surpassed them in 1929.

Comparisons and progress are sometimes best indicated by indexes and ratios, and some of the important ones are given here in tabulated form from data reported by the U. S. Bureau of Census.

Here it will be noted that the wage earners in factories increased at a higher rate than the population until between 1929 and '31, that the production quantity increased at a much higher rate than the production per wage earner, all of which is evidently due, in large portion, to the increase in installed power

Indexes and ratios for population and other data

Census Year	Population	Wage-earners	Production (quantity)	Production per wage-earner	Horsepower[1]	Horsepower per 1000 wage-earners[1]	Wage-earners per 1000 population
1899.....	100	100	100	100	100	211	63
1904.....	110	114	122	107	133	248	65
1909.....	121	137	159	116	186	287	71
1914.....	131	146	159	116	224	323	70
1919.....	140	191	214	112	294	326	86
1921.....	145	147	170	116	(2)	(2)	64
1923.....	149	186	261	140	332	377	79
1925.....	154	178	269	151	359	427	73
1927.....	158	177	272	154	390	465	71
1929.....	162	188	295	157	431	486	73
1931.....	166	139	206	148	(2)	(2)	53
1933.....	168	129	191	148	(2)	(2)	42
1935.....	170	157	227	145	(2)	(2)	58

equipment, which overshadows all other ratios in its rapid increase since 1899.

During the period since 1900 the number of proprietors and firm members has actually decreased to about half what it was in 1914, the ratio of wage earners to total persons engaged in manufacturing industries has also decreased about 1 per cent, while the number of salaried officers and employes has continued to increase almost without a break throughout this entire period. Figures are not available on these items since 1929.

Working Hours Decreased

Hours of labor per day have decreased from 10 and 12, six and seven days a week in most of the manu-

[1]Covers rated capacity of prime movers and of motors driven by purchased electric energy.
[2]No data.

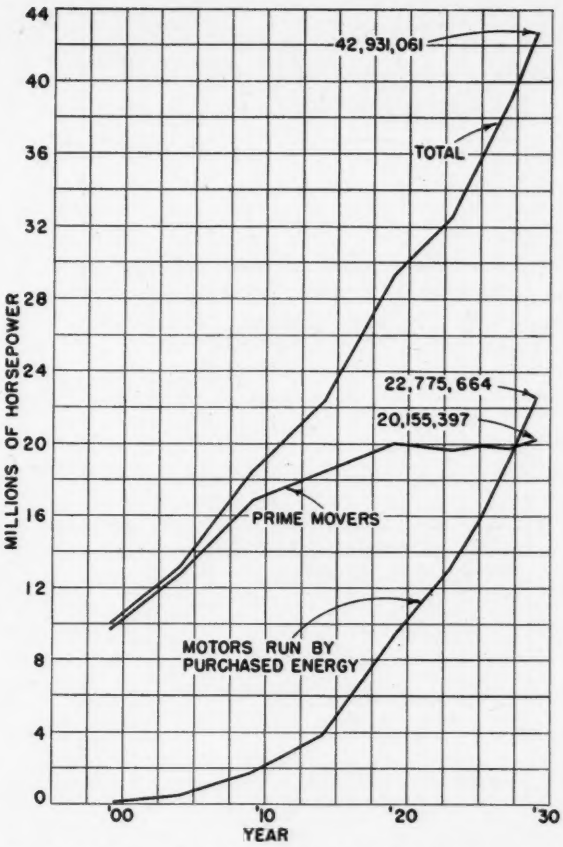


Fig. 3. Rated capacity in horsepower of installed power equipment

facturing industries to an 8-hr. day, 54-hr. week during the 1920's, when the country was most prosperous. Since 1930, however, the 8-hr. day and 40-hr. week prevail as a policy in most industries, the object being to spread the work among as many wage earners as possible in order to relieve the unemployment situation by some 25 per cent. Even with these reduced hours of work the average wage per year in factories was, as previousy cited, $1018, as compared with $426 in 1899.

Living conditions in factories today are universally recognized as so far superior to those of 40 and 50 yr. ago that it seems needless to do more than draw attention to some of the improvements. Plumbing and sewage systems are universally provided for factory employes. Pure drinking water, in many cases cooled, piped to convenient locations and dispensed through sanitary drinking fountains, has replaced entirely the water bucket in manufacturing establishments. Atmospheric conditions in which employes must work are maintained at the comfort stage of temperature in all plants and in many of the modern establishments, washed and humidified air is provided. Lighting conditions have been completely revolutionized. Sanitary restaurants are provided in factories of the larger sizes. Safe working conditions are required by law in all factories and studies are continuously being made to improve safety and prevent accidents. Medical attention is available in all large factories. Recreation facilities are provided at many factory establish-

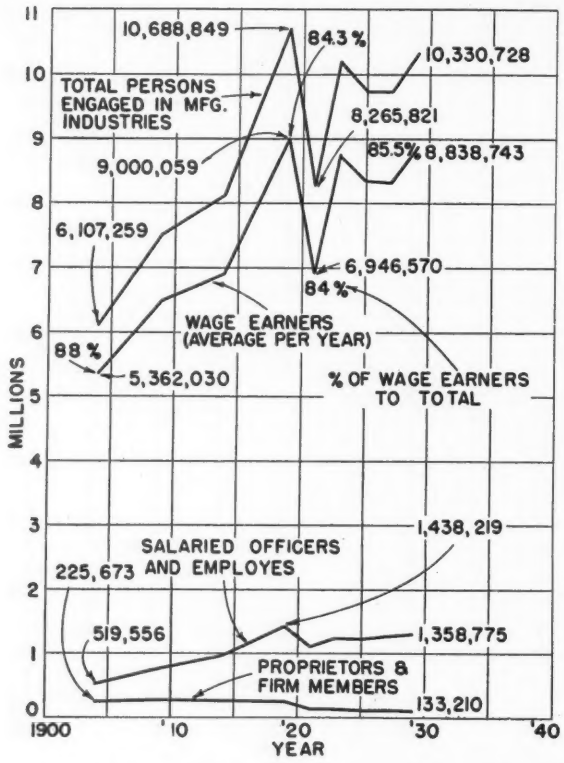


Fig. 4. Variation in number of persons engaged in manufacturing industries in the United States

ments, as well as club rooms, entertainment and lecture halls, banking facilities, insurance policies, pension arrangements and the larger companies maintain specialized employes whose entire duties have to do with personnel relations with employes, not only in the factory but in their homes as well. All of these improved conditions have come with the increased size of companies and developments in social conditions.

Improvement in Home Surroundings

Little need be said here regarding the home surrounding of factory wage earners as compared with what they were before the time power was made available in factories and residences. The housewife, it is well known, has been relieved of an endless amount of drudgery which she was compelled to do even a generation ago. With the exception of the pioneer electric lamps and the telephone, practically every electrical household appliance in use today has been introduced and been made economically available through manufacturing establishments since the turn of the century. In many homes cultural activities have taken the place of drudgery with further advance in the formal education of the youth of the families. Home conditions have also permitted female members of the families to join the forces of wage earners, in any cases undoubtedly replacing men on the employment roles.

Home environment has also been enhanced by the policies of many manufacturing companies who build their plants in decentralized districts where employes can build their own homes and have their own yards and gardens.

All these social changes that have taken place in the past 50 yr. to the advancement of human welfare cannot be credited to the development of the use of power in industry but it has been a mighty potent factor. Neither can the use of power be condemned as the sole cause of unemployment hardships during the periods of economic stress, for power is man-produced and man-controlled and the purposes for which it is used are the results of sociological conditions which permit abuses as well as benefactions in the employment of Nature's gifts to mankind.

The Factory Power Plant

Modern factory power plants are the outgrowth of the needs of the industry they serve and each industry has a set of specifications all its own. Emanating from this department of the industry are practically all the mechanical services required to carry on all the processes employed in the factory. Starting as a source of power to drive through shafting, belts and other mechanical means from water-wheels and steam engines, the plant was soon called upon to furnish steam for manufacturing processes, first at boiler pressure then at throttle pressures and later at exhaust pressures after the steam had given up energy for driving engines or turbines.

With the commercial application of electricity, the natural location for the generator was in the power plant where the equipment and controls would be under the constant attention of a skilled engineer. In the early days many air driven tools were developed for performing such services as drilling, riveting, chipping and hammering which have now been largely superseded by electric appliances but compressed air is still piped through factories from air compressors located in the power plant for such services as paint spraying, sand blasting and removing dust.

Water for all purposes, both raw and treated, hot and cold, is commonly piped from the power plant where the pumps are located close to the source of power and convenient for attention by the engineering staff. Likewise the preferred location for oil and chemical pumps serving process needs is usually in the power plant, if not they are driven by power supplied from the power plant.

In most factories, the logical attendant for the refrigerating equipment is the engineer of the power plant, so here again as the need is required an additional service radiates from the central source of energy. Along with refrigeration goes air conditioning—heating, cooling, humidifying, removing dust, pollen, tobacco smoke, offensive odors—and if this equipment is not located in the power plant it is almost invariably serviced by the power plant staff.

So numerous are the services rendered by electricity generated in the power plant and distributed to every corner of the modern factory that few people give any thought to other services rendered by this department of the factory. Although generated in the armature as alternating current, electricity was first commercially applicated in direct current form. This form had many advantages over alternating current in early applications to services now using both types of current, and it was not until the 1890's

that a.c. motors and control equipment were made applicable to many uses previously performed only by d.c. These developments also made practicable transmission of electric power to longer distances and gave birth to the systems of interconnected power plants that exist today.

With the commercial application of alternating current came also the development of the steam turbine as a prime mover to drive a direct connected generator, thus greatly reducing the space requirements and the amount of material required for construction.

Throughout the entire development of the factory power plant, constant attention has been given by engineers to increased economy in services to the institution served. Because of the diversity of the services they render, factory plants can usually make use of all their exhaust steam and thus materially reduce fuel expense. Many factories have waste materials that are usable as fuels for the production of steam. These, in some cases, supply the factory with part or all of its fuel needs.

Engineering developments in the design of power equipment, heat cycles employed, operating methods, instruments installed, controls for combustion and other processes have been and are continuously being made not only to improve the economy of the services rendered but to insure safety to the attendants and continuity of operation.

Contributing Industries

Like many other industries, that represented by the power plant has called for the development of many manufacturing companies to supply the equipment that goes into power plants. Up until 75 yr. ago about the only principal manufactured equipment that goes into power plants was boilers, engines, pumps and their accessories, all of which were in a primitive stage of development. The development of this industry has brought about the establishment of practically all electrical equipment manufacturing companies, steam turbine companies, concerns manufacturing condensers, internal combustion engines, air compressors, air tools, stokers, pulverizers, and greatly augmented the output of companies manufacturing boilers, engines, pumps, piping, instruments and all types of power using machinery.

It may well be said that the industrial power plant is the controlling point of all factory operations as carried on in modern industry, its service in promoting human welfare is immeasurable, industries have been born to serve its needs and many future industries will come into being because of the services it renders.

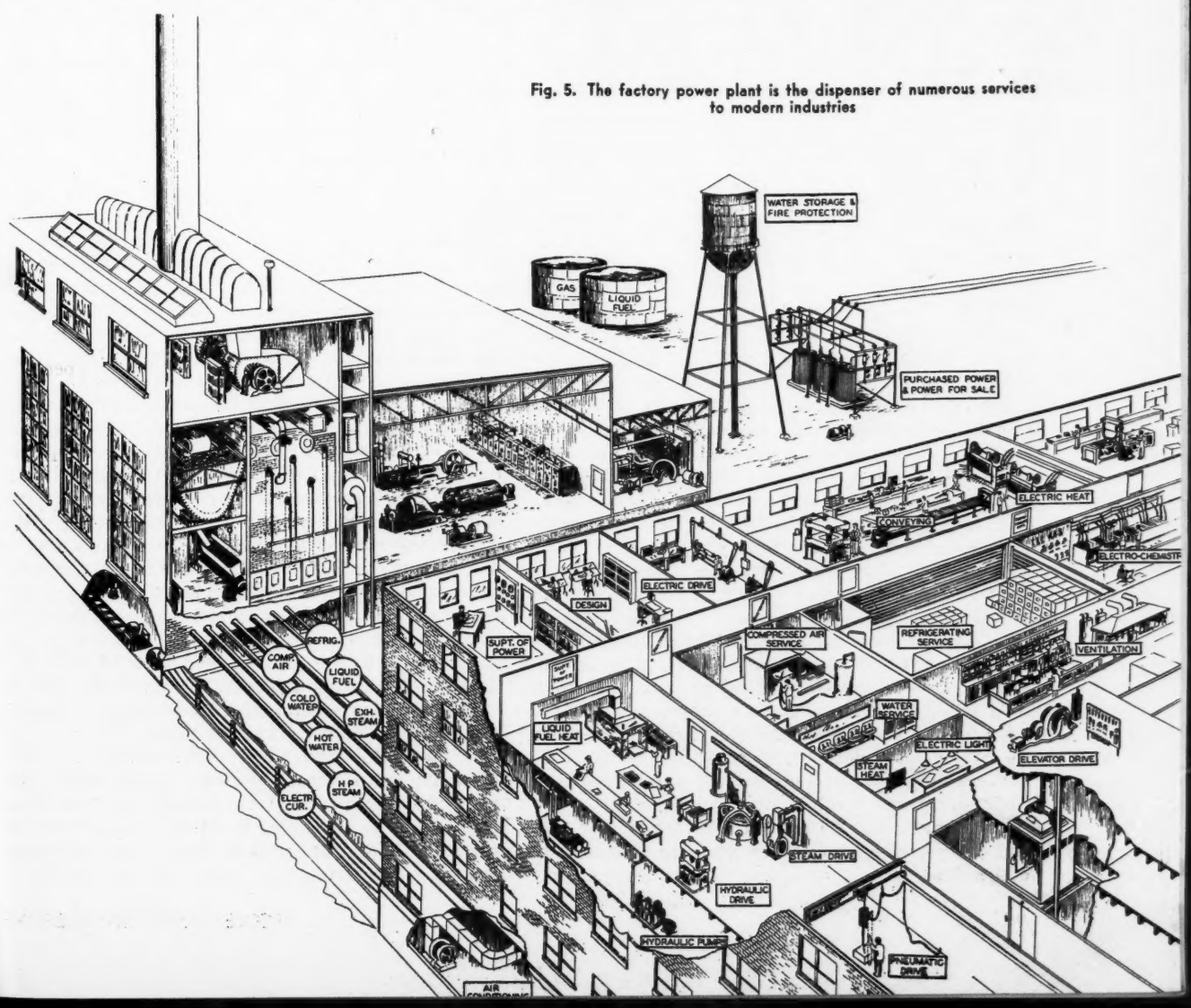


Fig. 5. The factory power plant is the dispenser of numerous services to modern industries

LABOR And

Workers at Grand Coulee

Photo, Bureau of Reclamation.

THE HISTORY OF POWER is the history of civilization. No more important question is presented to our generation than the right use of the instruments for the creation of power, whether private or public. In the earliest society muscle power was the only power known to man. By the muscle power of slaves were the Pyramids built, by the muscle power of captives and slaves were the triremes of the Roman Empire driven over the Mediterranean, by the muscle power of man and beast were cities built and commerce carried on. When early man discovered the principles of the wheel and the lever, two new inventions had come to augment the power of man's muscles—inventions of far-reaching importance.

One day man, who had seen the fury of the hurricane, sought to harness the power of the wind in his service and a new milestone in the history of man's advance had taken place. Ship sails and land sails gave new power to man's efforts and extended his knowledge of the world. It was wind power which pushed the prows of the Pinta, the Nina, and the Santa Maria under Columbus' command across the Atlantic to the shores of the New World in 1492. For more than three centuries thereafter sailing vessels plied the Seven Seas and launched the Era of Discovery. As early as the twelfth century the use of windmills for pumping water and threshing grain, especially in Holland, marked another advance by man.

One day, also, man had seen the fury of the flood and the power of falling water, realized that there was another source of energy which could be harnessed for his service, and the water wheel was invented, in the days of the Egyptian civilization, to help in the irrigation of the Nile Valley. Today the water wheel has given way to the turbine, but water still continues to be one of the great instruments for the creation of energy that has been brought under the subjection of man.

In 1776, at the time of the Declaration of Independence, Watt, the Scotch inventor of the steam engine, finally succeeded in getting his water pump to operate at fourteen strokes to the minute. It marked perhaps an even greater epoch in the history of power. With it began the Industrial Revolution, which was to transfer the character not only of industry but of our civilization. It was to mark the rise of the modern labor movement. No longer was man dependent upon the wind for his power, nor even upon the occasional interruptions in the flow of water. The steam engine meant that wherever man was able to move wood, coal, oil or gas there he could develop his own prime mover and develop sources for the operation of industry.

Electricity

With the advent of electricity and the development of electrical energy that could be generated either by steam or by water, still another and perhaps more significant milestone was passed in the creation and distribution of power. Wood, wind, water, coal, gas and oil are all capable of being transformed into electric power—the most fluid and usable power known. This development has marked the culmination of man's struggle over the centuries to bring the forces of nature under his subjection. In large part, then, the historical development of technology is the story of man's achievement in converting, controlling, and utilizing the energies latent in natural resources.

Today electric power has become one of the basic determinants in our capacity to produce, distribute and consume goods. Nowhere has power been more amply generated and more widely distributed than in our own country; nowhere in the world have we seen such a disposition to make power the aid for the production of goods and services. Behind the back of every American workingman there are, according to one estimate, approximately thirty horse power, whereas in the nearest competitor, namely England, there are but fifteen horse power behind each workman, in Germany there are but twelve. In China, until recently, there was less than one-tenth of one per cent of horse power at the back of every Chinese coolie.

The POWER INDUSTRY

BY MATTHEW WOLL

Vice-President, American Federation of Labor
President, The Union Labor Life Insurance Co.

Of course it is true that in different countries there are different forms of power that are still being made available. Some countries use wind, water, steam, and electricity; others tend to specialize on the latter two. While it must be evident to anybody that advancing technology and the expansion of power are today the outward signs of our modern civilization, while there are other products of the mind and of the human spirit which are important in the fashioning of a civilization, the basic thesis of my article that the history of power is the history of civilization, is still essentially true.

Labor

But in the long story of the development of power there have been occasions when the labor community has been apprehensive about what would be the effect of the coming of new instruments of power upon their old occupations. When the water wheels of Egypt were first developed, the water carriers of that country, who had earned their living by carrying water up from the river bank, went on strike. When machines were first introduced into the textile mills of old England, there were strikes of the weavers and literally the smashing of the machines which they saw taking their places. When in more recent times cigar makers saw machines coming into their industry, they opposed their introduction because it would mean loss of employment to them. In the printing industry, however, the advent of the linotype was readily accepted by the printers and rapidly became an important part of their own mechanical equipment.

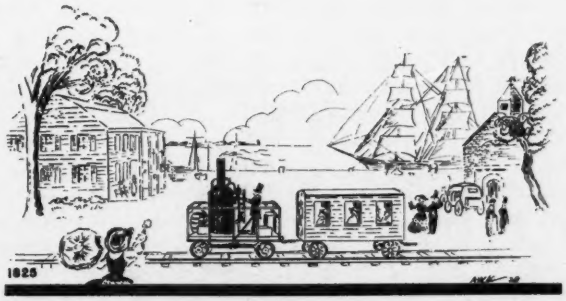
In the main American labor has never attempted to block technical progress. To the contrary, it has steadily maintained that progress in all fields should be deliberately directed toward human progress. Increasingly labor has accepted new machines and new equipment and appropriated them to their own use and to the larger service of industry. For labor now knows, after its long history, that the coming of power and its wide utilization has in fact liberated them from serfdom. The machine has indeed given man a new freedom, which he is gradually learning how to use in the service of others.

Unquestionably machine production results in lower costs, brings lower prices and more goods are sold, so that employment often exceeds that of the pre-machine age. Then, too, this cycle of expansion brings social progress in the form of higher standards of living, and eventually workers share with other citizens the progress due to technical improvements. But, however, they have had to bear a disproportionate share of the transition from the old to the new. Nor have these costs been only financial losses, serious as they are—unemployed workers pay in the form of starvation, cold because of no fuel, loss of home and home possessions and the misery of watching one's family deprived of the essentials of life. Then, too, workers discarded from industrial life through technological transition too often find themselves cast irretrievably on the economic junkheap because a new process has mechanized or eliminated entirely the phase of production at which their hands were skilled.

The interests and welfare of workers ought and must be considered in all the adjustments involved in the machine changes. If industry acts arbitrarily, ignoring the welfare of workers, it invites opposition by workers in the industry wherein they are ignored. This is in general the background for proposals that workers employed under former conditions should have the first lien on jobs using the new machines and that increased productivity should be accompanied by a reduction in hours of work. This has also given rise to the conviction that just as machines should be provided with the necessary safety devices before they are installed for use, so the labor aspects of technical changes should be the subject of conference and agreement between unions and management before the shift is made. Society has a right to require such procedure because society must help pay the cost of unemployment and permanently discarded employees.

Unemployment

Unemployment due to displacement of workers by machine has been a serious problem since the beginning of the 18th century. It has become increas-



By 1825, the steam railroad was making the world smaller

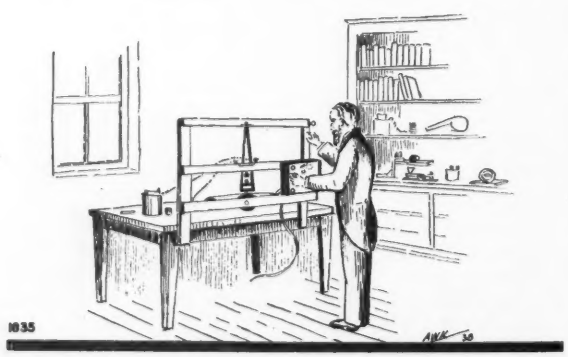
ingly acute since the early years in the 20th century. Electric power heralded a new machine age. Every class of worker from a machinist craftsman to a ditch digger has felt the repercussion of new machine tools. The workers instead of generating work and lifting power within his own body controls high-powered machine tools that make his experience and judgment effective over a much larger volume of output. Two labor problems have never been thought through and determined in the light of facts of the new power age—the daily and weekly work hours and adequate compensation for new rates of productivity. For the most part industrial managements have only been willing to compromise by adding a bit to rates and reducing hours under pressure.

Formulation of principles for determining wage and hour standards in this new power age would go far to revolutionize our distribution of the proceeds from joint work and assuring purchasing power adequate to maintain mass production now technically possible. In our enthusiasm for technical progress our Nation has forgotten that all production and all progress must promote human welfare. By dedicating our industries to the welfare of those small groups whose incomes are derived from profits, management created the causes of our present economic breakdown. Only by distributing equitably the gains from joint work can permanent prosperity be maintained under an electric-power economy. Mass production assumes mass consumption; shorter hours and higher wages are the keys to mass consumption.

Here are some of the distressing facts that are in stark contrast to our practically unlimited capacity to produce. One-third of all families live on less than $780 annually; one-half have incomes under $1070, and two-thirds have an income less than $1450. Nearly four-fifths of all families (79%) live on incomes less than $2000. Of our national income $59,000,000,000 for 1935-1936, one-third went to the poorest group of families with incomes under $780. It is obvious that higher wages for the low income groups would practically all be spent to buy the products of industries and would help to maintain mass production to capacity.

Considering justification for higher wages from a standpoint of what workers produce, we find that the average worker produces twice what he did twenty years ago—that is for every hour of work, the worker produces nearly double the units of output. For every 100 units produced in 1919, he produced 154 in 1929 and 191 in 1938. The normal work week of 58 hours in 1890 has been reduced to a normal 40 hours, but the actual work time per week has been reduced to 34 hours by the irregularities of depression.

In connection with these two facts we should consider the huge army of unemployed now numbering 11,000,000 and never below 7,000,000 since 1932. To exclude permanently so large a portion of the population from the ranks of producers and income earners is unthinkable and economically impossible.



In 1835 Samuel F. B. Morse produced the first electric telegraph

Control of Power

We must bring mass production in a power age into accord with a sound program of human welfare and permanent prosperity or perish by reason of our technical success. Because of these and other considerations, the question of power—who is to control it, how it is to be made a more serviceable instrument for the community—has become one of the paramount public issues. Shall we have government ownership or can we continue under a system of private enterprise? This is one of the issues which is before the American people. Labor is not only concerned in the right answer to this question but feels that it has, out of its general interest in the common welfare, something to say which is of importance on this great matter of public importance.

In the first place, American labor, with its aim and purposes conditioned by our American scene and way of life, adheres to no doctrinaire philosophy on what is the most desirable form of society for our own country. Labor knows that it was under a system of private enterprise that this nation was developed and made the greatest manufacturing nation in the world. Labor is aware as well that it was under private enterprise that labor received the largest share of the national produced income of any group of workers in the world. Labor believes in the institution of private capitalism because of its deep conviction that under a capitalist form of society the rights of the individual are more consistently protected and guarded than under any other system. But in its general support of private enterprise, labor is not unconscious of certain monopolistic trends which have been taking place in American business.

In no field is the trend toward monopoly disclosed more clearly than in the field of public utilities. The average citizen does not willingly tolerate the existence of several different telephone companies or several different electric light companies in the same community. This is true of our transportation system. It most certainly would not tolerate the existence of several different water companies. These are what are sometimes described as natural monopolies. Over a period of years it has been the developing opinion of the citizenship, in which labor has played an important part, that where there is the strong tendency and almost assured possibility of monopoly, there the question of regulation and control by government seems to be the direction of sound public policy.

The question is sometimes asked as to whether or not it is possible to effect any kind of regulation and control of these public utilities in the public interest. It is asserted that regulation and control have failed and that government ownership and management has become necessary. Labor does not accept this dogmatic conclusion. It is not convinced either that regulation and control in some communities is the complete elimination of private enterprise in this field. But rather labor is of the opinion that where regulation and control is ineffective, it should be provided with some teeth; that there is sufficient power within the law-making branch of the government to delegate to administrative agencies the wise and sound administration of public utilities in the public interest.

Regulation of Utilities

Nor, on the other hand, is labor entirely unmindful of the fact that in connection with a good many of these public utilities artificial values have crept in. Whether or not in the evaluation of these plants it is the replacement value or the original or actual, prudent investment principle which should be used as a basis is again a subject that gives a certain administrative phase to this whole question. In general labor is inclined toward the use of the later standard of evaluation. However, what labor in its capacity as a consumer is concerned with more than anything else is that rates be as low as possible and as compatible with the payment of a reasonable compensation for administrative services and for amortization charges. Labor believes in a living wage not only for labor but for capital as well. It believes, as I have said before, in the institution of private property. It believes that property rights should be protected and in the long run properly compensated for when taken by excess condemnation.

Labor is unalterably opposed to waste, to duplication, to destructive competition, but labor also is committed to the democratic way and feels that it would be a great mistake to abandon business and enterprise in this country to a governmental bureaucracy. Nothing would more rapidly and more effectively undermine the very basis of a labor movement than the complete elimination of private enterprise and the dispensing with the right to hold private property.

In a word, then, as labor looks over the long history of power and views the present debate which is going on in this country on the subject, it applies to this question the criterion which it applies to other questions which affect the public interest, namely, the manner in which the public interest is served, the integrity of the person is maintained, and human values are kept inviolate. In the obligation of all business and all industry to serve the general welfare they may be described as public not private, and the obligation of all businesses whether public or private to so conduct them that the men and women who are a part of them and who are served by them shall not be exploited but rather helped, is the steadfast aim of labor. The question of who controls power is from the standpoint of labor then of less importance than the ethical standards that are carried forward in its general administration.

CAPITAL And The Power Industry

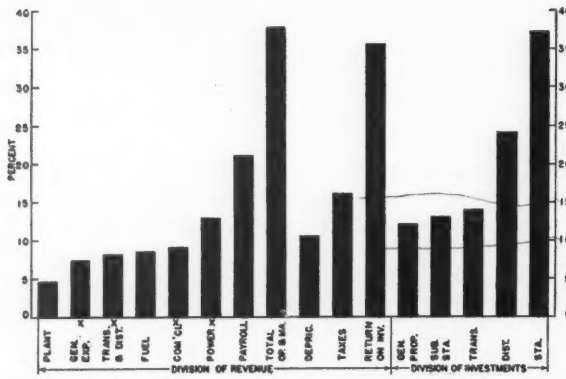
SERVING the nation with a hundred billion kilowatt hours a year is the task of the electric light and power industry, an organization of a quarter of a million people backed by an investment of approximately 13 billion dollars. In an earlier article Mr. Kellogg has pointed out that the payroll constitutes 21 per cent of the total cost of electric power.

Yet the industry is concerned with the conversion of energy from one form to another and depends upon the machine to accomplish what no amount of human or animal power could possibly do. Man is important for direction and control but as far as the actual production of power is concerned, the industry is the leading exponent of the thesis that power provides the means of true labor saving in production.

On the basis of the entire industry (only a fraction of which is engaged in actual production) each employee produces annually about 400,000 kw-hr. of the total consumed by the country. On the other hand, each dollar of capital invested produces only about 8 kw-hr. a year, an almost unbelievable emphasis of the importance of capital to the industry.

Return on the investment constitutes over one third of the total cost of power and is almost equal to the total operating and maintenance cost of the system. In 1937 the total investment averaged $369 per kw. of net generating capacity, which although a slight reduction from the peak of $373 in 1934, represents a steady growth from a value of about $325 in 1920.

This cost, analyzed by A. H. Kehoe before the last annual meeting of the E.E.I., can be further subdivided about as follows: Stations, 37 per cent; transmission facilities, 14 per cent; substations, 13 per cent; distribution facilities, 24 per cent; property costs, 12 per cent. Station costs have been steadily decreasing from $162 per kw. of capacity in 1920 to about $138 in 1937. This decrease was more than



Distribution of utility costs on the left show the importance of capital in supplying the nation with a hundred billion kw. hours a year. The annual revenue of the industry exceeds 2 billion dollars but the total investment in the industry is almost 13 billion dollars. Due to this low capital turnover the 35.7 per cent for return on investment represents less than a 6 per cent annually. Because operating and maintenance costs are broken down in several different ways, there is considerable duplication in the seven items at the extreme left. Four of these items, indicated by an X, are on the same basis and add up to the total shown for operation and maintenance. This last item with taxes, depreciation and return on the investment add up to 100 per cent of the revenue. The five items on the extreme right show the percentage distribution of the $369 investment by the industry for each kilowatt of net station capacity

balanced by transmission and distribution facilities which in the decade 1920-1930 expanded so rapidly that the investments more than tripled. Since then the growth has been more gradual and by 1937 amounted to about $52 and $46 per kw. of generating capacity respectively.

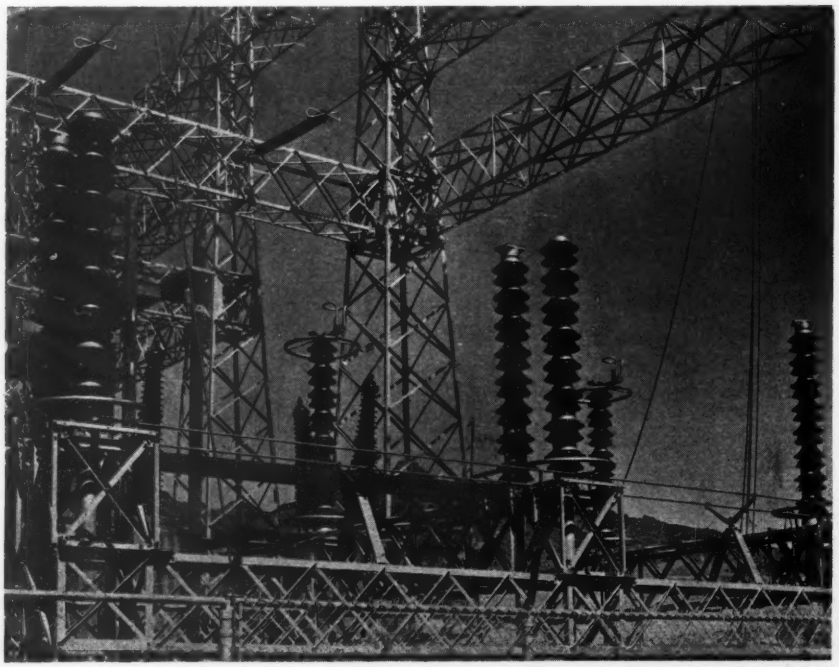
This era was characterized by system development, the connection of many small systems or properties into interconnected regional systems by high capacity transmission lines. Inasmuch as practically all cities and districts are now tied into systems future growth of these facilities is expected to be relatively small. Distribution costs, including services to the premises of the consumer have also been increasing steadily and now amount to about $89 per kw. of capacity, an increase of $32 over 1920.

Station costs mentioned above include both fuel burning and hydro capacity. The latter which constitutes about 27½ per cent of the capacity represents about 37½ per cent of the station investment. Unit costs of $250 per kw. in 1920 have been reduced to $187 per kw. in 1937. Steam station costs of $125 in 1920 have been reduced $5 to $7 per kw. of capacity in 1937 and is expected to drop even lower under the influence of the large number of topping turbine installations and further capacity.

It has been estimated that doubling present capacity, using present day prices and steam stations, would reduce the average 1937 station cost from $138 to between $125 and $130 per kw. Doubling the present steam station capacity in this way would reduce the national fuel average to around 1.2 lb. of coal per kw-hr.

Doubling the capacity, in a short span of years, has occurred time and again in the past and it is confidently expected that the same thing may happen in the next decade. At present unit costs this would mean a capital investment of something over 10 billion dollars, or, an average of a billion a year. This is not excessive for private utility expenditures almost equalled this in 1924 and 1930 and averaged over 800 millions annually for the period from 1923 to 1930.

The tremendous importance of new capital in relation to the continual growth of the industry is apparent. In the past the holding company has played a dominant part in the expansion of the industry and well over one-half of the nation is covered by about 50 of the larger systems. Rapid territorial expansion is no longer possible and the secondary stage of industry growth, excepting certain areas which will be affected by the necessity for absorbing large blocks of Federal hydro power, will of necessity be along different lines than in the past. Most of the new capacity will be steam, probably additions to present stations well situated in respect to load and to the needs of integrated system operation.



Station costs are but a portion of the investment necessary for the electric light and power industry. Investment in transmission, substation and distribution facilities exceed station costs by almost 50 per cent

POWER And Our SOCIAL SYSTEM

BY WILLIAM J. KELLY
President, Machinery and Allied Products Institute

AMERICA today stands on the threshold of an era in which technology and power engineering can achieve for our generation and posterity goals of material well-being and freedom for spiritual and cultural developments beyond even the fondest dreams of our forebears.

We have tested and proved our physical sciences—the sources of our tools and processes for producing goods and rendering services. They have revealed illimitable potentialities. Only by bungling the social sciences—the economics of production and distribution, the political science of taxation and government, and the sociology of human welfare and happiness—can we block this step over the threshold and the advance on new economic and social frontiers.

We are just beginning to realize the significance of the fact that our whole American civilization is built on the foundation of technology. Over a period of several generations our government, our institutions, our customs and our mode of living have been developed and adapted to the conscious or unconscious urge toward progress through technological advance. On this foundation we have achieved the widest-spread high living standards the world has ever known.

Throughout American history this foundation and the social system built upon it have been constantly challenged, tested, checked and approved. With the coming of the depression of the 1930's, however, some have grown skeptical, and for the first time we have seen this structure seriously threatened.

It is only natural, human nature being what is, that the machine—the power age—should be blamed for the problems of today and that countless both vicious and well-meaning reformers should attempt to justify a wide variety of schemes for social change on the grounds that "technological maladjustments" make them necessary. Those who point to the machine and the power age as the source of today's social problems cite the fact that America's longest period of widespread unemployment and depression followed immediately upon the world's most notable era of technological advance. They contend that there are cause and effect relationships. More impressive, however, are the incontrovertible evidences of the benefits from technological advance such as these:

BENEFITS OF TECHNOLOGY

1. Employment throughout the economic system grew faster than population increased during the period of most rapid technological advance.

2. Technology is the principal factor responsible for America's high standard of living.

3. Technological advance is constantly preventing industries and individual plants from becoming obsolete and throwing men out of work.

4. Technology can be credited more than all other factors put together for the doubling of factory wages since 1914 and the quadrupling of them since 1900.

5. Technology has made possible price reductions which have placed the costly luxuries of a generation ago in the homes of millions in the low income groups today.

History proves that technological advance itself is the best corrective force to apply to many of the problems which some seek to correct by direct or indirect restrictions on technology. There is all but unanimous agreement among economists that the greatest potentialities for employment and momentum for recovery today lie in the capital goods industries—those which produce the machines and other property essential for the operation of a technological society. Only by normal activity in these industries can economic recovery for America be achieved and sustained. There is no substitute for it. Yet we are struggling today to maintain and advance a technological society under a set of national policies based on the delusion that prosperity can be achieved and sustained by curbing the flow of investment funds into capital goods and by restrictions of business and industry which discourage and prevent the maintenance and expansion of the nation's capital facilities.

Industrial recovery and social and economic progress can be achieved only when we have government policies which are adapted to the essentials of a dynamic growing technological system. Make certain that the normal processes of maintaining and advancing our technological system are possible and the most serious social problems growing out of economic depressions will largely disappear.

The most urgent of the social problems facing America today is unemployment. What are the effects of technology, of the power age, on employment? There are three major effects:

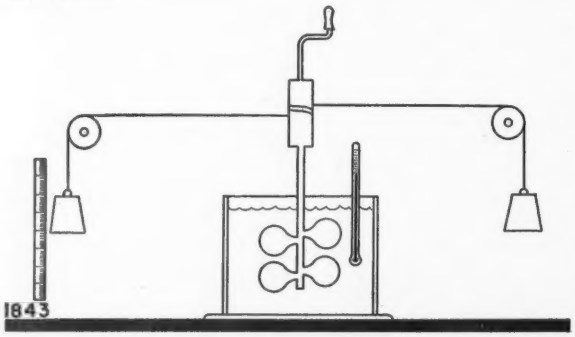
1. As a society progresses from the primitive handicraft form to one in which production depends principally on technology, there must be an ever increasing proportion of all gainful workers engaged in the construction and maintenance of capital facilities.

2. As the production of goods and rendering of services is mechanized through the installation and use of capital equipment, employment per unit of production declines. Total employment, however, is vastly increased by this process which reduces prices and increases volume of goods consumed. Employment grows in production, distribution and collateral services which are rendered as a result of the increased use of the goods produced.

3. As production methods are mechanized there is an increase in cost of capital facilities per unit of employment. Therefore there is an ever increasing need for the accumulation of savings to be invested in capital equipment if employment is to be increased or unemployment prevented.

Employment in a Power Age

From this it follows that the prime essential to recovery of employment and consumer purchasing power is a revival of investment of savings in private enterprise. Everyone connected with the power engineering field has at some time developed an idea or seen someone develop a product on which he was willing to gamble a few hundred or few thousand dollars because he saw the possibility of making a fortune. That is how our power age developed. Most of our businesses started that way. They would never have come into existence except for the venturing of somebody's savings. Jobs in the manufacturing industries have been created directly by this process. Jobs in trade and service occupations have been created indirectly by it. Goods produced as a result of these ventures found markets and consequently men and women found jobs selling them, handling them and transporting them. Advances in power engineering which have resulted from such venturesome investment have brought price reductions and have increased productivity which has raised wages and broadly expanded consumer purchasing power.



The discovery of the mechanical equivalent of heat by Joule in 1843 furthered progress in the science of thermodynamics and the understanding of the steam engine

During the decade of the prosperous twenties Americans ventured an average of about 1.7 billion dollars a year in new productive securities of private enterprise. That was the average amount of new stocks and bonds issued by private corporations for productive processes each year. In addition, large amounts were invested directly, without security issues, in industrial equipment and other property necessary for maintaining and advancing the standard of living to which we were accustomed. These funds made possible the replacement of worn out and obsolete equipment, the expansion of plants and the development of new products and new processes. They both created and filled an ever-growing demand for goods and services. They were regenerative.

Decline in Investment

Since 1930, however, American corporations have issued new productive securities at only about one-fifth the annual rate which prevailed in the 1920's. In the seven years preceding the great depression capital expenditures of public utilities amounted to $14 a year for every man, woman and child in the nation. Now the rate of such expenditures is about $4 per capita per year. Expenditures of railroads in recent years have been far behind the rate of obsolescence. The same condition prevails in the building industries. In the manufacturing industries there has been a smaller expenditure of funds in proportion to depreciation and depletion of equipment in the 1930's than ever before in history.

Why has the volume of venture funds not returned to the pre-depression level? There are a number of factors, but underlying all is one basic cause. That is, that in 1933 the federal government embarked upon a program of reform and instituted as national policy a set of economic principles entirely foreign to those which had prevailed in America when our great strides in industrial progress were made. Prospect of profit dwindled, business confidence lagged and new enterprises were not launched.

Controlled Distribution of National Income

The basic tenet of the reform philosophy is that national prosperity can be achieved and maintained by government regulation of the distribution of the national income. As an expression of this policy numerous pieces of legislation have been passed which were designed to increase consumer purchasing power and redistribute national wealth largely by diverting funds from investment channels into taxes and artificially increased wages. The theory is that if less is spent for investment, more will be available for consumer purchasing power.

The two securities acts, for example, though commendable in their purpose of protecting investors against fraud are so drastic that, along with other laws and governmental influences, they cloud new enterprises with uncertainty and prevent many American corporations from resorting to the security markets to raise funds for legitimate, socially and economically desirable productive enterprises which would produce goods, render services, pay wages and distribute purchasing power.

There are tax measures which penalize both individuals and businesses for responding to the normal and

wholesome desire to save for investment in productive enterprise.

There have been numerous pieces of legislation attempting to regulate competition. Some have pertained to prices, some to wages and hours, and some to other factors in production costs.

A Free vs. a Planned Society

The underlying thought in all of this legislation is that broad segments of our economy should be brought directly or indirectly under the control of a centralized plan administered by the federal government. This is in direct conflict with the traditional American system of free enterprise and the operation of a competitive system upon which our technological society has achieved its phenomenal progress in the past.

The most frequently advanced argument for economic planning is that a technological society such as that in America is too complex to operate without a centralized plan administered by government. On the contrary, it should be noted that the social sciences and the arts of government have not advanced at the rapid pace of technology and the physical sciences in general. There is much greater danger in placing today's society under the control of the plans of an individual or small group of individuals than there would be in attempting rigid control of a simple handicraft society.

The size and complexity of present-day business operations are already so great as to tax the managerial capacity of the most capable men available for places in directing single corporations. As size increases, complexity grows, and it grows out of all proportion to increase in size. No individual or group of individuals is capable of creating or administering a plan for the economic activities of an entire nation the size of the United States.

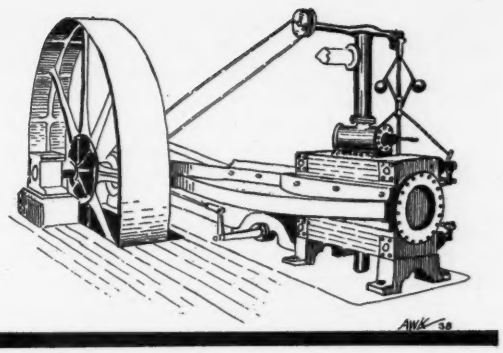
No, the solution to America's economic and social problems does not lie in a centralized government plan, but in an unshackled free enterprise system. Government planning is always in danger of directly or indirectly outlawing technological progress and industrial change upon which social progress is based. There are a number of evidences of this in federal government policies currently in effect or frequently proposed. Among them are the following:

Threats to Technology

1. The patent system is under attack for its alleged contribution to anti-social monopoly. Disturbance of the basic principles of American patent laws opens the door to the use of patent grants for punitive purposes, and to countless other conditions which might not only discourage but prevent technological advance.

2. Federal control of wages, hours and working conditions is predicated largely on the theory that government intervention is necessary to adjust dislocations resulting from technological advance. Public acceptance of this principle is a tacit acceptance of the converse application of it—government control of technological change for the purpose of improving wage, hour and working conditions.

3. Tax policies and legislation affecting investment are already curbing technological advance by decreasing funds available for research, experimentation and development of new products and industries. The ostensible purpose of governmental policies which lead to these effects on technological advance are to limit alleged excessive plant expansion, excessive profits which prevent proper distribution of national income, and excessive speculation which leads to economic and social losses.



The work of George Corliss greatly improved the performance. Here is shown an early Corliss engine

4. Corporation licensing by the federal government is advanced ostensibly to curb monopoly and to prevent other possible social abuses. This power over corporations, accompanied by other regulations already granted and proposed, leaves the way open to complete dictation as to plant expansions, equipment replacement, expenditures for product development and new inventions. Control of technological change would then be in the hands of government.

5. The belief that owners enjoy disproportionate benefits from machinery use has led to a wide variety of proposals for special taxes on machinery to raise funds to relieve unemployment. These proposals involve levies on horsepower, dollar investment, hours of use, and the like. This type of legislation is fraught with more danger than any other from the standpoint of limitation of technological advance.

Under policies such as these the wings of technology would be clipped and the advance of the power age would be forestalled. Under free enterprise we can have a dynamic industrial system in which the fruits of invention and engineering progress will be made available without restriction or interruption for the enjoyment of mankind. And under free enterprise we can also have a dynamic social system which will permit not only the attainment of higher material standards of living but freedom for spiritual and cultural attainments impossible under a system dominated by an authoritarian state.

Essentials to Social Progress

Technological change and the power age have brought us social problems which we must solve, but the history of America is replete with instances of our ability to solve such problems under a free enterprise system. There is no evidence in world history that these problems have been or can be solved by authoritarian governments.

Let us have a set of national policies which permits a revival of the flow of investment funds into private enterprise, and America's unemployed will find jobs.

Let the improvements in technological efficiency in power engineering which have been developed in recent years be incorporated in machinery and equipment which American industry can find funds to buy and put into use, and we will have a flow of goods and services which will again start our nation on its traditional road of progressively higher living standards.

Let there be free application of the traditional American policy of greater technological efficiency and lower prices, and the problems of distribution of the national income and the distribution of the benefits of the power age will take care of themselves.

Let there be encouragement of profit-seeking enterprise and encouragement of the development of new inventions and new processes, and there will be opportunity for individuals to find for themselves the social security which government can only promise.

These are the major social problems facing America today. Their solution lies in a resumption of the normal processes of building, maintaining and advancing the businesses and industries which constitute our technological society. Unless we resume these processes the very source of our social progress will be destroyed. These processes are more important today than they ever were in the past because we have grown to depend upon them. There is no substitution for them at the high plane of living to which America has become accustomed. We cannot discard them without our whole civilization collapsing.

The future of technology and of the power age, and therefore of social progress, depends largely upon our ability in America to apply to the social sciences the caliber of talent which the last generation has employed in the field of engineering. We have just begun to write the history of the power age. Most of it lies ahead of us. When business men, industrialists, engineers and leaders in every walk of life grasp the significance of the needs of the day and apply their energies toward gearing our social system to the power age, we can be assured that our gains in the future will be greater than even the dreams of the past.

Power as a National Problem

Continued from Page 17

is a transmission line. Ships and railways and motor trucks are left free to transport men and munitions.

The great power plants of the Pacific Coast—Boulder in the south on the Colorado, Bonneville and Coulee on the Columbia, and Skagit on the north—will produce a combined dependable output of four million horsepower, and an additional seasonal capacity of two million horsepower.

This power supports all kinds of industry in peace time. It irrigates great tracts and supports canning industries, the production of wheat and the production of many articles of food and clothing. It processes metals and metal products, wood and paper products, and their products for explosives. This production is necessary in peace and vital in war. The World War was largely lost by the failure of food supplies.

The great St. Lawrence plant should be built now. It is in the heart of the industrial districts to which it can supply 1,100,000 hp.

Its construction would be of inestimable value in the defense, not only of the United States, but also of her sister nation Canada. The two countries have a common interest in defense against the one enemy that could be effective, the aeroplane, and a common interest in furnishing material and supplies to be used against such an invader. The great generators of today need 2 yr. or more to build and install, and the great dams take 5 or 6 yr.

Does this mean that the great government plants should be installed now, or should we wait until the nation is attacked and finish them in the following 4 or 5 yr., after the damage is done? How long would it require to build them in war time, when the demand for other material intensifies manufacture, and transportation is needed for other things?

Once we knew that "in this age of civilized man war was unthinkable," but we have gotten over that thought about 20 yr. ago. Now we are convinced that anything can happen.

State regulation of private power companies is difficult at the best, and in many cases is a partial or complete failure, due to political intrigue over which the regulatory bodies have no control.

Some power systems have spread into two or more states, but their power rates must still be regulated by the individual states instead of by an interstate or federal commission.

In this field of private monopoly much assistance has been given the regulatory bodies by the sprinkling of municipal power plants built throughout the nation. Their influence has had a profound effect on the reduction of light and power rates.

Their number is comparatively small, about 3000, but they have acted as yardsticks. Their accounts are public and open to all, so their financial operations can be accurately analyzed. In the largest municipal plants a system of cost accounting is kept, so the cost of construction and operation of each part of a power system is pretty well known.

The greatest difficulty in the regulation of utilities was in the control of the bonds and stocks that were issued to finance them. This difficulty was overcome by the instituting of the Federal Securities and Exchange Commission. The issuance of all private bonds and stocks must now be approved by that Commission. The result is that the gambler in the pyramiding of values is a specter of the past. Private power must now earn its way by legitimate operation.

This may result in lessened activity in building private power systems, but it will certainly raise the operating companies higher in the estimation of the public. Any lessening of activity of private building will be made up by the building of public plants.

These public plants, especially on a national government-owned network, would do more to regulate light and power rates than all other devices put together. Such a network would eventually lead to a uniform rate everywhere in the nation, from Florida to Washington, and from California to Maine.

As long as the direct current lines and arteries of

the network were owned and operated by the federal government, there need be no discrimination in rates. Both public and private plants could pour their surplus into this network at a uniform sale price, and draw out their requirements at a uniform price, adding a fraction of a mill for the network operation.

A uniform rate at all plants connected to the line would give a uniform wholesale rate everywhere in America, and this would tend to uniform resale rates.

The increasing quantities of power to be used in future, and the higher voltages more easily possible with direct current, will make the cost per kilowatt hour over great distances very small. Regulation of rates will then come naturally and automatically.

Everyone knows what competition has done for the advancement of the world. Work was done mostly by hand. There was employment for all hands, and it was often difficult to get sufficient labor. Competition became more and more difficult as the years went by. Then began a struggle to lower the costs of all products. It was universal because competition was universal. It was individual because competition was mostly individual.

Individuality in competition began to give way to partnership and companies. The little red school house came, and the study of economic and engineering costs became more intelligent and systematic. The individual inventor was partly replaced by professional research men, and team work brought more rapid results. Costs went down, and an abundance could be produced with comparatively little labor.

But with the reduction of costs and the discharge of millions of men and women, we have not kept pace with social improvement. We have let our people shift for themselves, often after 20 or 30 yr. of the best of service and loyalty. We talk about "rugged individuality," forgetting that we have turned over all of our utilities to monopoly where there is no "rugged individuality" possible except that of the monopolist. He is the one who shouts for it, and for obvious reasons.

So much for Competition. He bowed himself off the stage in all our private utilities, and Monopoly bowed himself in.

Two power systems in competition cost the people twice as much as one. No one will dispute the fact. There is no mystic source of revenue. The people pay all the costs in any kind of power system. There is no other source.

Monopoly even with attempted regulation just didn't work, so Competition bowed himself in again as Municipal Power.

Rates for light and power tumbled. Here was a case where the people got low rates though they supported two systems.

Some localities went further. They instituted a public monopoly where the people owned the entire system themselves. That system did work, as for instance the Ontario Hydro and such cities as Tacoma and Los Angeles. The people handle their own property. They can change its management if they are not suited. Its profits go to themselves. They are working for development and progress, not for profit except in lowered rates to all.

So it has been proven over and over that while competition can and does bring down rates for light and power, public monopoly can far surpass it, and after competition has done its best, public monopoly can cut the rates again squarely in two, since two systems cost twice as much as one.

Thus in the State of Washington where huge federal and municipal plants have been installed, and in the State of Nebraska with its public districts, and in the T.V.A., there lies a choice of competition between public and private power, or a possible public monopoly where the private concern is willing to sell. The public monopoly will bring the lowest rates, so the public should have no hesitation in paying actual value after a proper study to find that value.

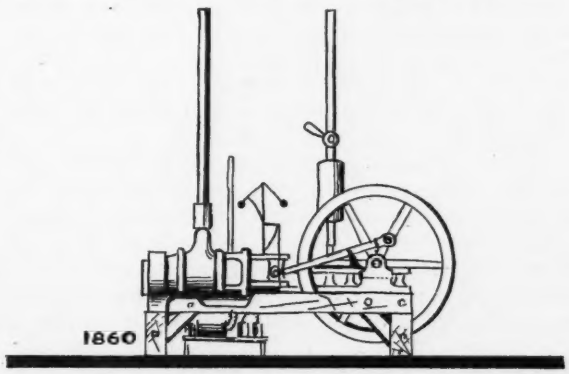
A power company represents a number of bondholders and preferred stockholders. Many of these stockholders are local people. If the bonds and stocks are called in at their proper value, much of the money remains at home, and in no case has there been any loss through the transaction. The rank and file of the personnel of the system acquired are supporting their families like the rest of us, and since the purchase is a proper one, they will be loyal to the new management, or more so, and may be taken over without hesitation.

It is better from the economic standpoint of both the public and the power company that wherever public competition is authorized, that a fair offer to purchase be made to the existing company, before competition is actually begun as a last resort.

If the offer is rejected, competition becomes the only alternative.

Later the company may change its mind and be willing to sell. When that day comes, it will probably get a lesser price, as its facilities will have been duplicated by the public plant. The company will have paid for its part of the competitive battle in addition, so it will lose all around.

The public system will be built to duplicate the private system, and in addition it will pay for its part of the competitive battle. Even though the price to the company in later years may be less, the public will find that after they add the cost of competition and duplication, the total sum will considerably exceed a fair price in the first place.



One of the first successful gas engines was produced by Lenoir in 1860

Aspects of Power Availability

AS HAS BEEN INDICATED in other pages of this issue, man's entire existence is, and always has been, a struggle for the control and the use of energy. Until comparatively recent times, however, his efforts in this direction were rewarded by meagre success and until late in the 17th century when the first practicable steam engines were developed, his capacity for work and production was limited by his own strength plus that of domestic animals. This fact imposed severe restrictions upon his environment—upon his social and economic systems. Past civilizations rested largely upon human slavery; even in the finest civilizations of the past, leisure was afforded only to a few of the ruling class by the hard work of many slaves. Not until the day of the steam engine and machines arrived did an influence appear which could put an end to slavery and drudgery in human society. Mechanical power, enabling man to do more work, has enabled people of the civilized nations to develop in directions other than securing a mere existence. In this age of mechanical power, a premium is placed upon the superiority of mind over muscle, and human slavery is not only illegal but absolutely impractical because of the high cost of human labor compared with mechanical power. A mechanical horsepower costing $20 to $50 per year, substitutes for 10 to 15 human slaves; furthermore, a machine can operate continuously day after day whereas a slave cannot. Power means progress, relieving man of drudgery and enabling him to make the best use of his opportunities.

A human being, working at full capacity, develops on the average about a fifth of a horsepower—approximately 150 watts. Since the human being and the horse or equivalent draft animal were the only power producing "devices" before the coming of the steam engine, it is quite obvious that the amount of energy available to man in early times was considerably less than one horsepower per capita—probably less than one tenth horsepower per capita. This was the "energy availability" up to say the time of our Declaration of Independence. This figure of a tenth of a horsepower may seem small in view of the above estimate of a person's capabilities, but it must be remembered that a human being and an animal can work at full capacity for only a small number of hours per day, so the power output over the entire 24 hours of a day is very small.

With the advent of the steam engine, possibilities for the useful expenditure of energy increased enormously in one single bound. Even a crude steam engine working at low efficiency, could do the work of a hundred men and what is equally important, the engine did not become tired—it could work 24 hours a day, 7 days a week. In other words, by means of the engine the availability of energy at *that particular point* increased several hundred fold in one single jump. Of course, at first engines were few and far between so the immediate effect *per capita* was small, but for the first time the possibility of using more power existed.

It is unnecessary here to describe the growth in the use and application of the steam engine or how this growth resulted in the development of other machines for the utilization of energy—that side of the story is well known but the point to be emphasized here is the fact that in the sudden acquisition of a means for multiplying the use of energy hundreds and thousands of times man found himself face to face with a situation the like of which had never before appeared on the face of the earth.

He found himself possessed of a means of doing away with the muscular work of men and animals forever. In all the course of written history no era dawned with such devastating suddenness. It was the industrial revolution and it divided significantly all man's history following from what went before. Accommodation to it is still the basis for most modern social problems. It faces us with ruin and enlightenment and which of these it will give, no one can tell.

Effect of Power Concentration

The concentrates of power brought about by the steam engine resulted in machines of increasing complications and production became more centralized around them. As a consequence the inherent advantages of power driven machine production were offset by an inability of the human race to adjust itself to the new environment that resulted. Cities grew; for the clothes and the shoes, the weaving and the soap, the foods and instruments that were once made distributively throughout the land withdrew to urban factories for quantity creation.

Tremendously increased production brought the need for more rapid exchange and transportation of money and goods. Distribution and communication became mechanized; the world became smaller. Nations that once had been far apart became neighbors—bad neighbors mostly, envious and critical of each other, and ill feeling arose. Towns that once had been political or the foci of commercial distribution became centers of production and dragged under their dingy skirts the poor and the wage earners, forcing them to live in slums and unnatural filth and to labor in undifferentiated masses under men they never knew. The growth of wealth in the first quarter of the nineteenth century was startling but so also, to any who looked beneath the surface, was the misery and poverty among the workers and the chronic trouble of unemployment.

However revolutionary the coming of steam power and however disturbing its influence upon the old order of existence, the process so stated was only in its infancy. The modern state of the world, with its tremendous cities, its 70 story towers, its tubes and subways beneath streets and rivers and its 80 million dollar bridges could not have been born of a steam engine energy level. For these things something else

was needed and that something was the electrical transmission of energy.

As recently as 1899, according to an estimate made at the time by R. H. Thurston, with a total power development of 25 million horsepower in this country, the power available was about 2 *man-power* per capita of the population.

With the eelectrical transmission of energy with its infinite flexibility, the use of power increased enormously and today, with a total of over one and one-half billion horsepower available in the United States, we have at our disposal approximately 12 horsepower per capita. This compared to 1899 represents an increase of about 50 fold!

This figure of 12 horsepower per capita takes into account all the principal forms of power, including the power of motor vehicles. The latter accounts for approximately two-thirds of the total. The use of electricity for domestic use has increased greatly as the cost of electricity has been reduced. In terms of kilowatt hours per annum, the use of electricity for domestic use increased from 264 in 1913 to 359 in 1922 to 548 in 1930 and to 673 in 1935. The average cost of current for household use has been steadily reduced during this period; from 25 cents per kilowatt hour in 1882 to 9.1 cents in 1912 and to 5.03 in 1935.

Despite this increase in use of electricity neither the home nor industry is making full use of it. Apparently less than two-thirds of the urban population live in homes wired for electricity and less than one-half of those wired use electricity only for lights, doorbells and a flatiron.

Greater Use of Electricity Predicted

As time goes on, however, and development expenses are met, one can predict much lower prices for appliances and a consequent greater use of electric current.

This steadily increasing use and dependence upon electric power will make it more important to consider our electric power generating and distribution systems from a social standpoint as well as from economic and engineering standpoints. A few partial failures of the power supply in several of our large cities and the interruption of service over larger areas in time of floods and other disasters has demonstrated our dependence upon electric power only too effectively. Electric power has become almost as essential an element in our daily lives as the bread we eat and the water we drink. Modern civilization would collapse with failure of the sources of electric light power.

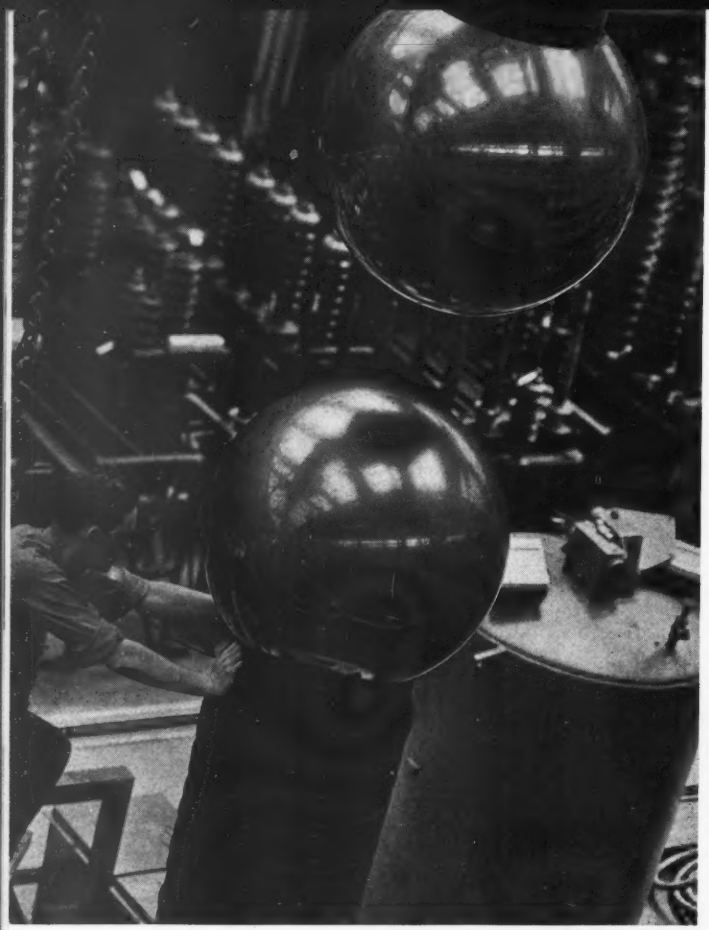
The need for adequate provision of electric power facilities and proper insurance against failure was stressed in the interim report of the Federal Power Commission several years ago. At the time the metropolitan papers and some national publications were inclined to take these remarks lightly. But it was not long before the same papers found themselves forced to report an actual occurrence of power failure in New York City, in almost the same language used in the warning in the Federal Power Report.

This occurrence and several other similar incidents indicate the need for coordination and interconnection in our national power supply. A considerable degree of coordination already exists and in the case of the Pittsburgh flood, the value of interconnection was clearly demonstrated. In this instance all power distributed in the flood area by the Duquesne Light Co. was obtained through interconnection. Even this borrowed power could be obtained from the Pennsylvania Power Co. and the West Penn Power Co. only because they in turn were able to borrow extensively.

Interconnection and generating facilities must not, therefore, be considered only from economic and engineering standpoints. The social cost of a single power failure might be many times the "economic" cost of a large generating station.

In other pages of this issue J. D. Ross, Administrator of the Bonneville Project. outlines a possible high tension direct current transmission scheme for interconnecting the great Federal Power plants in the west with the steam stations of the East. This proposal, as have all other unusual proposals in the past, has been discounted and criticized as impractical, but there is no real reason to doubt the practicability of this scheme and the next decade may easily see it put into effect. It is inevitable, if our civilization is to go on, that power will be used in increasing amounts. We are fast approaching the point where the price of power can no longer be determined by the scarcity value. Power is the ability to do work. It is the effective cause in any and every project to transform the world into a place more appropriate to man's desire. Its distribution is the primary problem. Man has come suddenly into a hundred horsepower world with social and psychological habits adjusted to a one horsepower world.

Thomas Edison produced the first successful incandescent lamp in 1878



The Influence

BILL SMITH, works engineer, engaged in a study of cost reduction in heating appliances, finds that the cost of the heating element proper constitutes an appreciable part of the total cost because it involves a great many manual operations and because errors in carrying out these operations result in a large number of rejects. Smith goes to John Jones, design engineer, to talk over his findings. Jones, the designer, cannot conceive of any way of improving his design with the insulating materials available to him. A meeting is arranged, calling in Bob Weber, research engineer, to discuss the problem. After some discussion, Weber suggests the development of some new insulating material entirely different from that previously used for the particular appliances but similar to a material recently developed for other purposes. In order to use the new material effectively, the design is changed considerably and new factory equipment for applying the material to the heating element without much manual manipulation is installed. The final result is a worthwhile cost reduction and improved operation of the appliance. In this case, the initiative was supplied by Smith, the works engineer; the basic idea making radical improvement possible, by Weber, the research engineer; and this was followed by considerable work on the part of both Jones and Smith.

In another instance, Weber, the research engineer, has discovered a better material and wishes to apply it somewhere to advantage. He presents it to Smith and Jones, who work out practical methods of manufacture and ways for applying it advantageously to designs. Many other examples varying in the sequence of events and of causes and results could be cited. (As in the stories in "True Story" magazine, the names used here are fictitious but the occurrences are true and rather commonplace in modern industry.)

In the electrical industry of America, happenings as just described are one of the main causes for the increasing total consumption of kilowatt-hours and the fact that the consumption per capita is greater here than in any other part of the world. (Electric energy used in the United States in 1937 was 100 billion kw-hr., or 100 times the power used in 1892, when production first crossed the billion mark.) This article gives some convincing evidence and examples to support this claim.

Factors Influencing Cost Reduction

The curve in Fig. 1 gives the actual story of the cost of a rather common electrical rotating machine. It will be seen that in a period of 20 yr. the cost has been reduced to approximately one-half of the initial cost. The curve shows a number of sudden drops followed by a more gradual decrease over a period of time. Inquiry as to the reasons for this type of drop has brought out that some of them, as the one at A, are due to major redesigns; others, as at B and C, to major rearrangement of factory set-ups; and still others, as at D, have resulted from a combination of redesign and improved factory arrangements. The more gradual decrease following the sudden change is brought about by a great many minor refinements in the new design or manufacturing processes, or in both. The question arises as to what part the research engineer might have played in this case. It so happens that in this particular type of machine no sudden change in cost can be attributed to outstanding research work. However, the research worker has contributed very definitely in a great many ways to both the sudden and the gradual changes indicated in the figure; continuous improvements in magnetic and insulating materials resulting from research have played an important part in the entire story. If another type of apparatus, such as a circuit breaker, had been selected as an example, one of the major and sudden decreases could very likely have been attributed to research.

When reviewing technical advances, we are prone to look for outstanding accomplishments and contributions, as, for example, the invention of the autovalve lightning arrester, which was a research contribution. Again, we might cite the change from cast-iron to welded steel designs in large machinery as a major contribution by the design engineer. In

# of Research on Use of Power

By R. E. HELLMUND
Chief Engineer, Westinghouse Electric & Mfg. Company

factory equipment, we are inclined to think of the straight-line production as originally introduced by the automobile industry. While it is true that these outstanding accomplishments have played an important part in industry, it is found that in most cases the grand total of numerous small advances is responsible for the greater part of all progress being made. Even the sudden drops in the cost curve previously discussed which are due to major redesigns or changes in factory set-up, are caused not so much by some outstanding new feature as by the fact that when a redesign or factory change is undertaken, many minor improvements resulting from development work previously carried on can be introduced at the same time. In other words, the greatest percentage of all advances is being made by the continuous plodding along of what might be termed the "industrial triplets"—namely, the research, the design, and the manufacturing engineer, or the Webers, Joneses and Smiths, all of whom contribute appreciably to technical progress. Possibly the design engineer, who is the center and keeps in close contact not only with both ends but also with the commercial department and the customers and whose function it is to utilize in his design information gathered from all sources, is more frequently in a position to initiate and stimulate desirable action and also to contribute a little more than his research and works partners.

Effect of Research on Power Consumption

In addition to the type of cost changes discussed this far, Fig. 1 shows a number of sudden decreases and increases, such as E, F, G, and others, which are primarily due to decreases and increases in wage rates. It will be noted that as a rule, increases in rates eventually are more than offset by subsequent improvements; however, it has not been possible to compensate fully for the increases in wages or for certain increases in the cost of materials which have occurred during the last several years. Judging from past experience, ways and means undoubtedly will be found to do this, although it becomes more and more difficult to make further improvements in apparatus which has been improved over a great many years. Figure 1 tells an interesting story of what has been accomplished in a period of 20 yr. In the earlier stages, it was possible to make even greater progress, as is illustrated in Fig. 2 showing the reduction in size and weight of induction motors of a certain make, starting with the first commercial motor of this type. In most cases the decrease in cost is accompanied by improved and more serviceable devices. At times improvements are demanded which mean additional cost, but here the extra cost is justified either by better service rendered or by the cost reduction possible in the operation of the device, or perhaps by cost reductions possible somewhere else in the system. Whatever the circumstances may be, the desired result is usually accomplished by the cooperative efforts of our "triplets."

But what has all of this to do with the increase in power consumption? This question, in one of its aspects, can be answered by reference to a household device which is relatively expensive and the increasing use of which has been appreciably influenced by its decreasing cost. The refrigerator is a good example of this. Curve A in Fig. 3-A shows the reduction in the price of refrigerators made possible over a number of years by cost reductions such as described in connection with Fig. 1. Curve B gives striking evidence of how the sale of refrigerators has increased with the decrease in price and largely as a consequence thereof. Digressing for a moment from the major purpose of this discussion, it may be

The Central Station Industry began with the opening of Pearl St. Station in New York in 1882

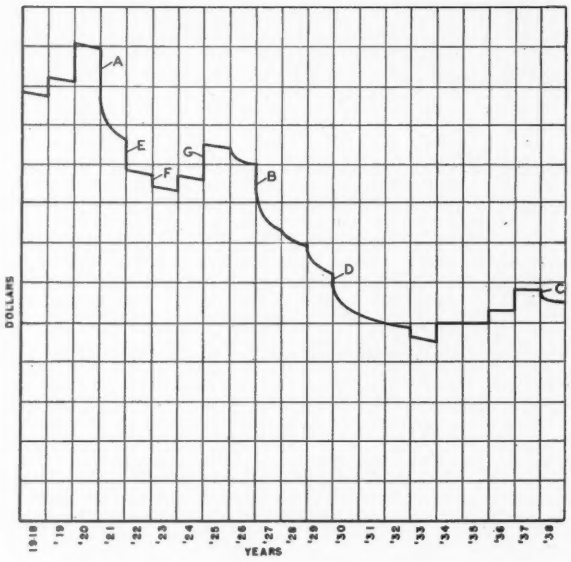


Fig. 1. Cost variation of a common electrical rotating machine

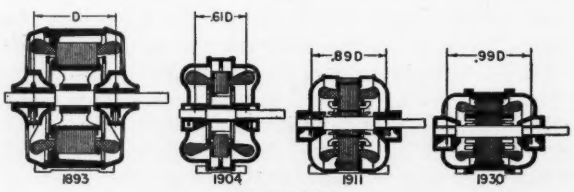
pointed out that the condition indicated in Curve A is the one so much talked about as being responsible for technological unemployment. The common belief in this theory, however, can be readily discredited simply by multiplying the price per refrigerator of Curve A by the number of refrigerators manufactured, thus obtaining Curve C, which gives the annual refrigerator business in dollars and, as such, presents a picture of the wages and salaries received by those engaged in the refrigerator business. It is hardly necessary to point out that wages and salaries have been greatly benefited by the continuous reduction in cost per unit and the resultant increased sales—Curve C speaks for itself. It is true that the increased use of electric refrigerators has resulted in decreased sales in ordinary ice boxes; however, the increase shown in Curve C is such that there is little doubt that the total earnings of all those engaged in both the old and new refrigerator manufacture have nevertheless been materially increased.

In order to reach some conclusion regarding the amount of power consumed, the average life of a refrigerator has been assumed to be 8 yr. (probably less than the actual life), and using this as a basis, Curve D in Fig. 3-B has been derived to approximate the total number of refrigerators in use. Curve E indicates how the annual power consumption per refrigerator has been reduced by the improvements made each year in models of the leading manufacturers. This, together with a gradual decrease in power rates, has, of course, been an important secondary factor in increasing the use of refrigerators. Since at any one time many older refrigerators are still in service, the average power consumption of all refrigerators in use is, of course, higher than indicated by Curve D. Allowance must also be made for certain makes of lower grade, with higher power consumption. Curve F has been assumed to allow for these conditions. By multiplying the values of this latter curve by the total number of refrigerators in service, Curve G is obtained. A 10 per cent downward revision of these values seems justified to allow for installations in summer or winter homes occupied only part of the year. This leads to Curve H, which gives a good graphic picture of the enormous increase in power consumption contributed by refrigerators.

The decrease in the first cost of refrigerators and the increase in efficiency are not the only factors causing the increased use of refrigerators and their resultant total power consumption; the many improvements in refrigerators also have been important contributory factors. However, with the prices and cost of operation lowered, the features giving better service and appearance have assumed greater importance recently and will be even more essential in the future. Even if liberal allowance is made for the effect of promotional activities carried on by both the utilities and manufacturers, our "triplets" unquestionably should come in for the largest share of the credit for the increase in power consumption indicated in Curve H. Digressing again for a moment to consider the effect of the increased power consumption upon wage earners, it is at once evident that the latter have greatly profited through the manufacture of apparatus for generating and distributing energy and through increased employment with the utilities as a result of the increased use of power. The benefits derived thereby by the workers are without doubt far in excess of any losses incurred by those previously engaged in the manufacture and distribution of ice.

The Incandescent Lamp

Let us now consider a current-consuming device, the increasing use of which was influenced more by the decrease in its operating expense than by its first cost. The incandescent lamp is a good example of this type of device. Survey Fig. 4-A shows the decrease in the cost of lamps over a number of years. However, the cost of the lamps represents only about 5 to 10 per cent of the total cost of lighting, the remainder being expended for current consumption. Curve B in Fig. 4-A shows approximately the decrease in kilowatt-hours required by incandescent lamps for a given amount of light. Curve C shows for part of the same period the decrease in the rate per kilowatt-hour for residential use. Multiplying the values of Curve B by those in Curve C, Curve D is obtained, showing the decrease in the average cost per unit of light to the consumer. Curve E in Fig. 4-B shows the number of lamps sold each year for a period of 13 yr. Since lamps have a rather short life, which is proportional to the hours of operation, this



MOTOR WEIGHTS

YEAR	RATING A	RATING B
1893	774	1640
1904	230	740
1911	175	645
1930	145	515

Fig. 2. Size and weight reduction of a particular type induction motor

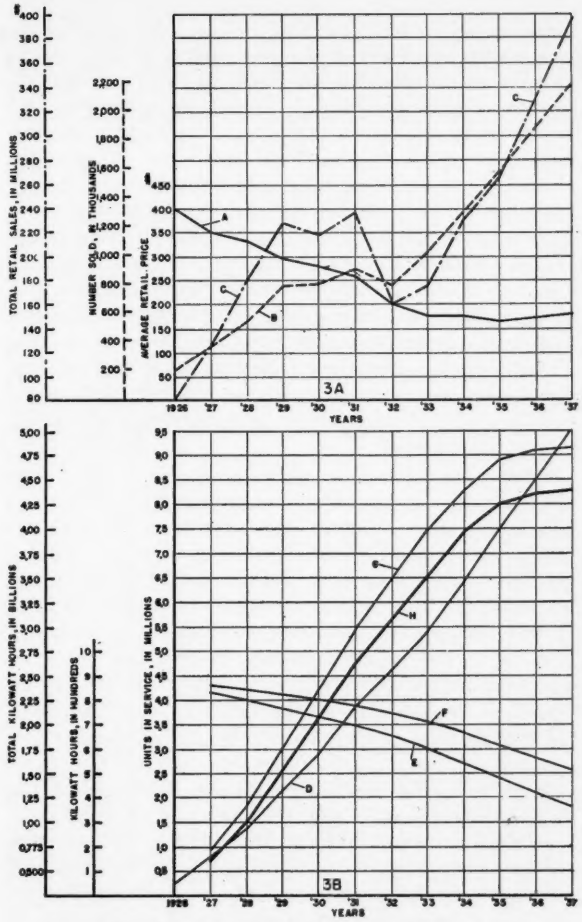


Fig. 3. Electric refrigerator data plotted to show variations

curve should be a pretty good measure of the product of the number of lamps installed and the number of hours they are in use. If this is further multiplied by the values in Curve F, which shows the increase in the average rated wattage of the lamps sold, we will obtain Curve G. The latter should be a fairly good indication of the increase in watt-hour consumption for electric light. It is seen that the reduction in cost per unit of light as indicated by Curve D is accompanied by an increase in the total of kilowatt-hours consumed. The reasons for the improvements in the price and efficiency of lamps have been discussed frequently in literature and we find that they can again be attributed to the joint efforts of the research, design, and manufacturing engineers.

The case of the electric range may differ somewhat from either of the previous examples inasmuch as both the first cost and the operating cost are important. However, the lowering of the first cost, accompanied by marked improvements in operation and appearance, together with the lowering of operating rates, is bringing about a much increased market acceptance of the range. With the flatiron, which combines for most domestic conditions a moderate operating cost with a moderate price, conditions are again slightly different. Improvements such as adjustable automatic control, high speed obtained by high wattage, and many other conveniences, very likely present the most important reason for the enormous increase in sales of flatirons. This point of view is supported by the fact that the sales of the higher priced irons, with all the latest features, compare very favorably with the sales of the low-priced non-automatic irons. However, as in all previous cases, our "industrial triplets" deserve much of the credit for the increased power consumption thus brought about.

This same group has, of course, contributed considerably toward the reduction in the cost of generating and distributing power and the consequent reductions in power rates such as indicated in Curve C of Fig. 4-A.

Figure 5 shows three interesting curves, Curve A giving the amount of coal required per kilowatt-hour. The reduction in this figure can be attributed to the joint efforts of the utility engineers and the manufacturer. The improvement in this instance is due not so much to cost reduction of the apparatus used for the purpose but to the increased efficiency of the apparatus used in the generation of power. At first glance, the flatness of Curve A during the later years would seem to indicate that possibilities for further improvements may be exhausted. However, if we recall the particular economic and other conditions affecting the utilities and the resultant temporary period of low construction, we may conclude that this latter circumstance probably furnishes the explanation of the apparent absence of progress during that period. As an example of important advances made, we can cite the recent introduction of the hydrogen-cooled alternators driven by high-speed, high-pressure steam units and the economies resulting therefrom. Let us see what has been the sequence of events leading up to this latest advance. The superior qualities of hydrogen as a cooling means was pointed out by

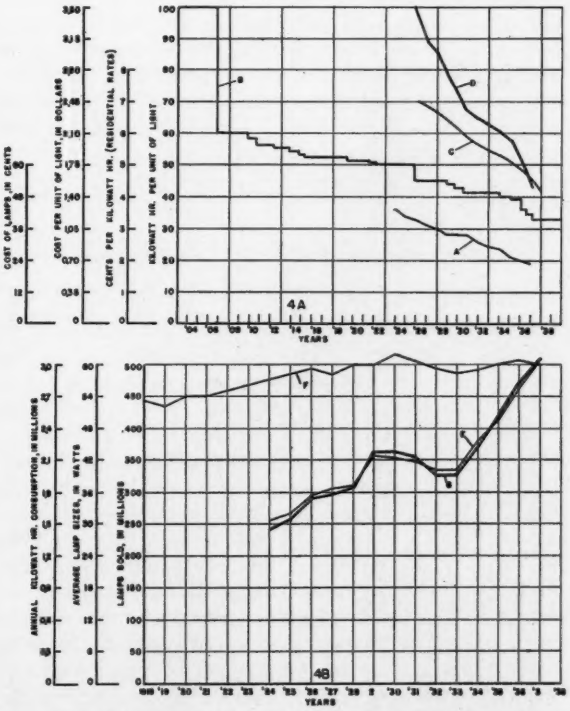


Fig. 4. Electric lamp statistics plotted to show effects of improvements

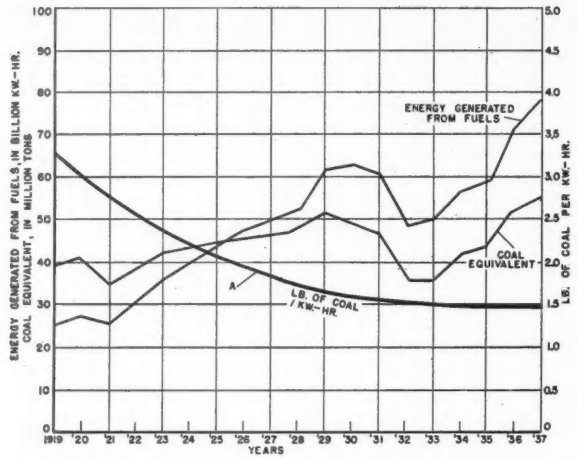

ENERGY GENERATED FROM FUELS, IN BILLION KW.-HR. COAL EQUIVALENT, IN MILLION TONS
LB. OF COAL PER KW.-HR.
ENERGY GENERATED FROM FUELS
COAL EQUIVALENT
A
LB. OF COAL / KW.-HR.
YEARS
1919 '20 '21 '22 '23 '24 '25 '26 '27 '28 '29 '30 '31 '32 '33 '34 '35 '36 '37

Fig. 5. Improvements in operation indicated by drop in fuel consumption per kw-hr.

the research engineers, who also undertook extensive investigations which supplied the basic data for the application of hydrogen cooling to machine design. The design engineers developed machine housing and bearing glands to eliminate leakage and losses of hydrogen from other causes. On account of the better properties of the new cooling medium, larger machines could be built for the higher 2-pole speeds. Here, the research engineer again contributed in obtaining suitable material and basic mechanical data for the high-speed rotors. The higher speeds of the generators paved the way for steam turbines operated with higher temperatures and pressures. Again the research engineers came into play by carrying out very extensive tests and investigations. Much of this work related to the development of materials suitable for the high temperatures and basic mechanical data for their application. The designer had to conceive suitable constructions permitting operation at high speeds and high temperatures, and the works engineer came in for much advance work in the way of refinement of manufacture, reduced tolerances, and shop equipment suitable for accomplishing these results.

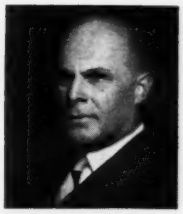
Cooperation the Secret of Success

However, the cost of coal is only a part of the total cost of electrical energy. Another large part of the cost of energy delivered to the customer is due to expenses for transmission and distribution and the apparatus for these purposes. The contribution of the manufacturers in this work may be made either through cost reduction in the apparatus, as previously illustrated for motors and refrigerators, or through marked improvements in operation of the individual devices, which in turn will enable the utility engineer to improve his service or his operating costs. The high-speed circuit breaker may be mentioned as an example of a device which has greatly improved service in connection with transmission systems. In cases of this kind, it is frequently the research engineer who does the basic work making advances possible. The De-ion principle of circuit interruption is a striking illustration of this. As in most cases of this nature, however, the initial event of the conception of an outstanding advance in the principle of operation was followed by continuous further improvements in the arc-rupturing devices through the activities of the design engineers, and, finally, by their development of high-speed mechanical design features. The contribution of the works engineers in some such instances may be limited to a great many minor activities for improving the processes of manufacture. As an important contribution to the distribution problem, the completely self-protected distribution transformer as developed over the past several years may be mentioned. If space would permit, a long and interesting story of the sequence and interrelation of various research and development activities could be told.

The few examples given here show very conclusively how in the electrical industry of the United States the improvements and cost reductions in all kinds of apparatus contributed by our "industrial triplets"—the research, design and factory engineers—have been one of the most important factors in increasing electric power consumption. I firmly believe that these accomplishments are due not only to individual ability, but to a great extent to the excellent cooperation of the three types of workers as well as to the cooperative spirit in our industry in general. I am quite familiar with the methods and activities in the electrical industry in some of the European countries, and I know how progress frequently is impeded there by invisible barriers between different departments of industrial organizations and also between different manufacturers in the industry. Probably the greater tendency toward cooperation in this country has been fostered by our historical development, during the earlier stages of which men had to cooperate to conquer nature and its resources, while in Europe, with its dense population and limited resources, the keener competition between individuals and groups of individuals has resulted in conditions less favorable in this respect. Let us be sure to hold fast to our inheritance so that we can continue to lead in technical and industrial progress in the future as we have in the past. Let us give the Smiths, the Joneses, and the Webers of industry all the credit they deserve for the contribution to the progress of the industry, and let the Smiths, Joneses and Webers continue in their friendly spirit of cooperation so that even greater progress in industry will be possible.

Speaking somewhat more broadly, I believe we should strive to maintain the cooperative spirit prevailing in the entire electrical industry. This spirit, which seems to excel not only that of foreign industries but also that of many of the older industries of this country, is frequently evidenced by the liberal exchange of information on technical subjects between competitors through the presentation of papers and other means. There are also a good many examples indicative of a liberal policy in license arrangements on patents. All of this has materially assisted the industry in its vast expansion, greatly benefited the public, and is bound to be of equal importance in progress and rapid growth in the future.

This Issue and Our Guest Editors



C. W. KELLOGG

SETTING FORTH the technical aspects of the power industry concisely and logically was not easy but it was simple compared to the task of selecting outside authors with the background and ability to portray the economic, social, industrial and political effects of power on the nation and on the world. Inasmuch as evidence of these relationships is largely circumstantial, the cases must be argued deductively, the articles become expanded editorials and the authors, guest editors. They are all nationally known but we felt that you would like to know why each was selected.

For a generation the electric utility has played the dominant role in the production and widespread use of power. During this entire period C. W. Kellogg, M.I.T. '03, has been active in the industry, acquiring first hand experience in all departments from operation to finance. He is now Chairman of the Board of the Engineers Public Service Co. and President of the Edison Electric Institute. Through the most trying period in the history of the industry he has piloted the Institute courageously through the shoals of antagonistic legislation and government competition. He is the logical spokesman. He knows what the industry has done, what it can do and what it must have if it is to continue as an entity in the American tradition of private industrial enterprise. (Photo by Blank & Stroller.)

J. D. ROSS

Because of a lifetime of practical experience with power, close contact with the Administration and steadfast faith in the possibility of linking all major power sources in one large national system, J. D. Ross was selected to discuss government activity. For 36 yr. he has been chief engineer and since 1911 superintendent of the Department of Lighting, Seattle, Wash., a 60 million dollar concern, the envy and pride of all municipal power enthusiasts, and, whose Skagit River Hydro development ranks with the nation's finest. In 1935 he went to Washington, D. C., as chief engineer of Power Development of the P.W.A. He then served as a member of the Securities and Exchange Commission and since 1937 has been Administrator of the Bonneville Project with the responsibility of disposing of the power output and administering a construction program that, next year, will run up to one and a half million dollars a month.

D. M. MYERS

Water power is of course important but the bulk of power is generated from fuels. In this field many engineers can speak authoritatively but none have a broader background, wider experience or more optimistic outlook than David Moffat Myers, consulting engineer and graduate of Columbia University. As Advisory Engineer of the U. S. Fuels Administration he proposed the National Program of Fuel Conservation in Industrial Plants and carried out the program as Chief of its Fuel Engineering Division. His experience as consulting engineer to the U. S. Bureau of Mines and in the design and operation of innumerable industrial plants qualifies him to speak with authority and vision on fuel and energy sources of today and tomorrow. (Photo by Associated News, Inc.)

M. S. VITELES

The machine and power tend to change the working habits of the people and if they are to be used effectively the human factor cannot be neglected. Dr. Morris S. Viteles, Associate Professor of Psychology at the University of Pennsylvania and Director of Personnel Research and Training of the Philadelphia Electric Co., has done outstanding work in this field. He has been actively engaged in research and practice in industrial psychology for the past 15 yr. His laboratory research backed by practical field application has proved to be a long step forward in keeping round pegs out of square holes. Power can best be controlled by entrusting its use to those physically and emotionally capable of utilizing it effectively and safely.

M. WOLL

Labor as an integral part of modern production methods has never been completely satisfied with the machine, or rather with the way the machine has been administered. It was advisable to have this important group represented by someone who could speak with authority for labor as a class and yet have the background to see it in its true perspective as one of the trinity, Power, Labor and Capital, supporting the foundation of American Industry. These almost impossible specifications are met by Matthew Woll (Kent College of Law and Lake Forest University) who is not only vice-president of the American Federation of Labor but among other things president of The Union Labor Life Insurance Co., with a practical business man's viewpoint. (Photo by Harris & Ewing.)

W. J. KELLY

Again we were equally fortunate in finding just the right man to present the executive's viewpoint of power and its relation to modern industry. William J. Kelly, with a long experience in business and finance and now president of Arthur J. O'Leary & Son Co., writes as president of the Machinery and Allied Products Institute. (Photo by Moffett studio.)

R. E. HELLMUND

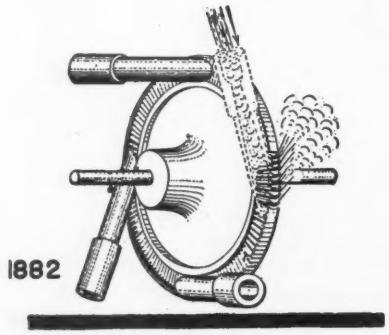
Industrial improvements are almost entirely due to research and development work carried on by manufacturers. The electrical manufacturers have always considered this an essential part of their business. Two of the major developments of this kind, the transformer and alternating current motor, are largely responsible for shaping the development of the electrical industry. Rudolf Emil Hellmund (Ilmenan Technical College and the University of Charlottenburg) played an illustrious part in both of these but his versatility in development work is evidenced by the fact that more than 300 patents are recorded in his name. He is now Chief Engineer of the Westinghouse Electric & Manufacturing Co. and writes on the effect of research on the use of power.

People in any way engaged in the generation and use of power are desirous of having their services meet every real need society can place upon them. They want power to be a long continuing benefit. They need public confidence in their objectives. The public needs an expression of these objectives.

AN APPROACH TO PUBLIC POLICIES

IN a symposium on power topics, such as has been gathered together in this issue, many conflicting ideas are bound to be expressed. This magazine does not assume responsibility for statements made by contributing authors, for each of the Guest Editors was given to understand that his written opinion would not be changed except for typographical style and slight space adjustments. This agreement has been carefully carried out in the presentation which is made here and the Editor of POWER PLANT ENGINEERING must state frankly that he does not agree completely with all the opinions expressed nor the deductions made from statistics presented. He does feel, however, that the approach to the solution of any problem so complicated as that now facing those engaged in the generation of power can best be made by gathering together all available facts pertaining to the case and the opinions of the leading minds of the country familiar with the various phases of the problem.

It is this type of approach to the formulation of national power policies that has been attempted in presenting this issue. An historical outline of power has been given; actual data on power plants have been presented; fuels used and their amounts and sources have been treated in considerable detail; social implications as gleaned from history and observations have been cited as objectives and aims in the field of power generation; the contributions of scientists, engineers, laborers and capitalists have received careful attention in this presentation of facts. Having all these data as background, one may turn to the opinions of national authorities represented by our Guest Editors with a feeling of confidence that judgment of statements can be fairly made.



The turbine industry began when De Laval built a practicable turbine in 1882

As was to be expected, there is considerable duplication in the statements in the various articles, each author, of course, being desirous of laying the foundation for his opinions. The statements of facts are expressed differently but are in substantial agreement. Much confusion exists, however, in regard to census figures, particularly those dealing with manufacturers. For a time rather complete data on power were gathered and published but, for some reason, this government service has been abandoned.

To those in any way connected with the generation and use of power, there is a source of inspiration and pride in the fact that power as generated today has developed into a major industry within practically one generation and, as all seem to agree, its social benefits have vastly improved living standards.

This development has come almost entirely as a result of private initiative with capital raised through the sale of stocks and bonds supplemented by earnings of operating companies. This is as true of industrial plants as of utilities. Until recent years, private capital alone has been responsible for every major improvement in power equipment from its scientific conception, through the development and experimental stage, to successful application in industry. Some of the extremely large and unusual hydroelectric plants recently built and now under construction are practically the only exception to the above statement. With such a record of rapid and continuous advancement there seems no reason why the country cannot depend upon private enterprise to carry on the development of the industry into every field where the economics of the situation warrants. The principal stated objective of public ownership advocates is that rates for electric service can be greatly reduced, which is a very doubtful claim when all factors are taken into consideration.

Criticism is at present being directed at the private utilities for their apathy in providing greater

capacity in their generating plants in view of the present high and growing load. This condition does, of course, require immediate consideration but up to this time steps have always been taken in sufficient time to prevent a real power shortage and the public need feel no alarm about such a condition so long as a reasonable return is allowed by governing bodies on the required investment.

Private utilities for many years have been operating under restrictions imposed by utility commissions and, while this arrangement lacks perfection, it has given the public the reasonable protection it requires against excessive rates and has permitted returns to investors that have not stifled the industry. Any government policy which would radically upset this fairly balanced condition would be a grave mistake.

As a rule electric utility systems operate as monopolies, a practice which, under public control, is definitely to the advantage of the community. Under such conditions public interest is frequently aroused by the charge that no competition results in excessive rates and that comparative standards are not available. Many arguments, both pro and con, might be given on this statement; the fact remains, however, that electric rates have, almost without exception throughout the entire country, continuously decreased in the face of rising costs in nearly every other major industry of the country. This, of course, is as it should be, as long as scientists and engineers continue to improve the economy or power generation.

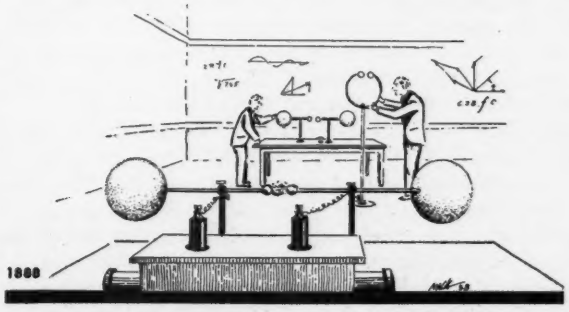
All power authorities seem agreed that the benefits derived from the use of power warrant its extension to the economic limit. The warning is sounded, however, that these benefits must be distributed more liberally down into the lower income brackets than has been the practice in the past. With such a policy there are few who will take exception. This is a problem with which management must cope. The introduction of labor-saving machinery cannot be done ruthlessly in large factories without causing labor disturbances. Personnel managers of leading concerns recognize the human obligation of softening the unemployment blow caused by technological advancement, but where competition is keen the problem is not simple and industry needs to develop methods where such changes can be made without severe hardship falling upon workers.

Probably the most important problem facing the entire power field today is that of fuel. Although our resources are estimated as sufficient to last for some thousands of years, many authorities are definitely concerned and are advocating restrictive measures to conserve fuel resources, particularly oil and gas. Very definite improvements in the use of fuel for power generation have been made since the first of the century but there is still room for improvement in heat economy, particularly in the smaller steam generating plants where obsolete equipment is still in service.

To all those in any way connected with the generation and use of power, we propose consideration of the following practices as general policies to be voluntarily carried through as individual and collective aims, firstly for the general welfare of all classes of people of the country, secondly, as a means of earning a livelihood commenserate with the desirable service performed:

1. Encouragement at every opportunity of private initiative in furthering the generation and use of power as a service to industry and the public.
2. Give support to government ownership and operation only where need exists for power, and private initiative has failed to supply that need adequately.
3. Insist that *every* power generation and distribution undertaking be based on proper economic returns to capital, management and operating personnel.
4. Demand that the equipment installed be of the highest efficiency consistent with safety and economy.
5. Vigilantly press for economy of nonreplaceable fuels.
6. Plan for the widest availability of low cost power by
   a. Providing complete network for interchange and distribution.
   b. Utilizing spare power from industrial plants, particularly those using waste fuels.
   c. Using to the full extent all developed water power.
   d. Recognizing that power supply is a public service and carries obligations on management and operators to avoid interruption when humanly possible, each class of service should carry its own real cost, with reasonable but not excessive returns to investors.

The power industry has laid a sound scientific and engineering base upon which it has developed in a remarkably short time a necessary service to civilization, the breadth of which is only beginning to be realized. Continued growth depends more upon good public and industrial relations than upon science and engineering developments which are far in advance of the general field of industry. Sound policies are, therefore, essential and with consistent cooperative effort the various elements of the industry can make their ideals known and secure acceptance by the public.



The Radio industry and to a certain extent the entire field of electronics is based upon the original researches and the discovery of electric waves by Hertz in 1888

Mechanical Engineers Meet

Scientific and technical developments given direction by consideration of human needs and desires for mechanization in social and industrial life of the nation at the Annual Meeting of the American Society of Mechanical Engineers held in New York City.

MEETING in New York City, as is required by its constitution, the American Society of Mechanical Engineers, for the fifty-ninth time, carried through its program of society business and technical affairs with a registered attendance of some 2500 persons, in the Engineering Societies Building on December 5 to 9. Next year, however, the major portion of the program will take place in Philadelphia with only the legal requirement being fulfilled in New York.

As always, the technical papers and reports of progress reflected the thought and work of mechanical engineers during the past year and many new designs and accomplishments in the way of research and application of the principles were made known and discussed at these technical sessions. It is noteworthy, however, that each succeeding year more attention is being given to the human phases of engineering.

Not only the Towne Lecture delivered on Honors Night by Gerard Swope dealing with the subject "Mechanical Engineering—Men, Materials and Methods," and at the annual dinner, the Thurston Lecture by Howard W. Haggard on "Physiology for the Engineer" and the Presidential address by Harvey N. Davis on "An Engineer's Philosophy" had for their theme the engineer's relations with men, but at several technical sessions papers on human engineering were read and discussions entered into by universally large audiences.

Officers chosen for the coming year were reported by the tellers on Honors Night as follows: President, Alexander G. Christie, professor of mechanical engineering at Johns Hopkins University, Baltimore, Md., widely known throughout the world for his work in the design of power plants. He was born in Manchester, Ont., Canada, in 1880, graduated from the School of Practical Science, University of Toronto in 1901 and received his M.E. degree from the same school in 1913. Vice-Presidents: Wm. Lyle Dudley, vice president and chief engineer of the Western Blower Co., Seattle, Wash.; James W. Parker, vice president and chief engineer of The Detroit Edison Co.; Alfred Iddles, associated with The Babcock & Wilcox Co.; H. H. Snelling, engaged in the practice of engineering in the patent-law field; Managers: Clarke F. Freeman, Wm. H. Winterrowd and Willis R. Woolrich.

Among those to receive awards was Francis Hodgkinson, consulting engineer and professor at Columbia University, who was presented with the Holley Medal for meritorious services in the development of the steam turbine.

Gerard Swope, president of the General Electric Co., has been one of the most outstanding humanitarians the country has known and in delivering the Towne Lecture, he expressed thoughts that could to advantage be formulated into national policies. "As I look back upon it now," said Mr. Swope, after citing some of the work of Towne and Taylor, "I remember quite clearly the emphasis that was placed upon these two factors—materials and methods. Important as they are, there is another element even more important that the engineer must recognize, and that is men.

"If management—the engineer—and labor find and interpret the facts of industry and come to peaceful conclusions as to the correct solution, there will be less occasion for laws compelling compliance, with the attendant evils of lack of cooperation and of rigidity."—Gerard Swope.

"Unfortunately, too often little thought and attention were given by either the management or the engineer to the resulting problem of the workingman. The engineer could and can interpret these factors—that with better materials, better machine tools and better methods of production, costs can be lowered, with a shorter work-week and higher earnings for the workman. Indeed, it is largely because of the work the engineer has done on planning in the shop, and especially in connection with mass production, that industry in America was able before, during and after the N. R. A. days to materially shorten the work-week, with increased wages; and now, again, to accept the minimum wage and maximum hours that are being imposed by law, without the disruption of industry, such as has occurred in other places where similar laws were put into effect.

"Technological unemployment does occur, of course, when better methods and better machine tools are introduced, but this need only be a transient phenomenon. Nevertheless it must not be overlooked, and either industry or society, since they are the beneficiaries, must help to protect the individual worker. If you look back through the history of

In 59th Annual Convention

industry, in America particularly, you will see that many more thousands of people are employed in manufacturing today than were employed years ago, with the labor content of each article reduced but a greater number of articles produced and used by many more people throughout the nation. It is now beginning to be generally recognized that the development of industry must be and will be along the lines of *more goods for more people at less cost.*

"The workingman must not be left without an understanding of this development. The engineer, busy with materials and methods, has paid too little attention to the human element that is inevitable in production. Neither the engineer nor the workingman, particularly in a republic such as ours, wants to be regimented."

Alexander G. Christie

Steam Studies

Of recent years the steam cycle as employed in the generation of power has been going through considerable change and as these new cycles have now proved their applicability beyond a doubt, engineers find themselves lacking in some fundamental information and ready means for calculating factors used in the design of steam using equipment. In an effort to supply part of these needs, one technical session was given over to the general subject of thermodynamics. Ronald B. Smith of the Elliott Co. approached the problem of calculating steam-turbine reheat factors from the analytical standpoint. Relations were derived for the reheat gain in the saturated and superheated steam regions, which show the influence of pressure ratio, temperature, efficiency and number of expansions. He reported that a comparison between his calculated reheat and the reheat computed graphically from the Keenan-Keyes properties of steam indicates good agreement over a wide range of conditions.

Further studies on the characteristics of steam were reported by Joseph H. Keenan of the Massachusetts Institute of Technology who had undertaken to determine the friction coefficients for the compressible flow of steam through tests with steam and water on commercial 1-in. pipe. The results of these tests were discussed together with their relation to the Reynolds number and Frossel's experiments. This paper also restated the analysis of flow of a compressible fluid in a passage of uniform cross section without introducing difficult concepts.

Each year the demand for greater accuracy in tests results brings forth new methods and instruments which are presented to the members of the society for criticism and ideas for improvement. At this meeting Harold W. Semar of the Westinghouse Electric & Manufacturing Co. described apparatus for testing models of piping installations to determine the forces set up in the full-size installation due to expansion. The method consists in fixing one end of the model in a slide which can be moved a measured amount, and measuring the forces at the other end by means of a fixture which holds that end rigidly in place and permits measurement of six forces in three coordinate planes, which are the equivalent of forces in coordinate directions plus moments in coordinate planes. The slide of the movable end is placed so that its direction of motion coincides with the direction of the pipe expansion. A complete example was given showing the steps in determining the end reactions of an inlet pipe for a steam turbine.

Reporting on a case study, Albert E. White of the University of Michigan, described changes in a high pressure boiler drum to eliminate recurrence of cracks due to corrosion fatigue. The boiler investigated was No. 5 at the Edgar Station of the Boston Edison Co. and the study was undertaken for the purpose of determining the cause of the cracks. The report discussed the cause of the cracks found in the water columns and in certain of the superheater fittings and headers of this same boiler. As a result of the investigation it was not felt that any of the difficulty could be attributed to faulty metal. The material was of the proper chemical composition and had suitable physical properties.

The primary cause of the cracks was believed due to corrosion fatigue resulting from stresses set up by changes in temperature on the surface of the metal in combination with a relatively low pH value of the water which was at times in contact with the metal that developed cracks.

As a result of the removal of the cracked metal and the changes in design which would prevent fluc-

"Today, the engineer goes into every field touched by man and there he creates for men new and changed environments. Each creation, each change involves a reaction—a physiological response. Each creation and each change, since it affects all situations which have existed before, becomes, not a mere addition, but a completely new problem to be solved in its totality. In every such problem of engineering there is this physiological factor."—Dr. Howard W. Haggard.

tuating temperatures on the surface of the drum at the boiler feedwater inlet, as well as other design changes which would raise the pH value, particularly in the water columns, further cracking is not anticipated.

Power Plant Studies

An overflow audience in the Auditorium of the building marveled at the colored motion pictures illustrating some of the phenomena relating to slag in furnaces which E. G. Bailey of Babcock & Wilcox used to dramatize his discourse on the fusing temperatures of various kinds of coal ash and slag, and their significance with respect to furnace temperatures, operation and design.

In the course of his address, Mr. Bailey suggested a method of comparing furnace operating results which consisted of (1) taking accurate gas temperatures throughout a furnace, (2) then calculating from them the rates of heat absorption in different zones, (3) calculating an "equivalent heat-receiving-surface temperature" for each zone, (4) taking samples of ash and slag from different portions of the furnace and determining the fusing-temperature range from such samples, (5) plotting these data as a "gas-ash temperature graph" against heat-absorbing surface, (6) comparing the data as shown on such graph with observed behavior of ash and slag in the furnace, and (7) comparing different furnaces, different coals, and methods of operation through the use of such graphs. Examples of the use of the method were given.

It was pointed out that this paper included data from only four installations but the results were so illuminating that it was deemed to be to the benefit of professional progress to publish the data and method of comparison now, so that others active in this work can utilize what has been reported.

Progress made in the generation of power in industrial plants has in general lagged behind that in central stations. This criticism, however, does not apply to those recently built plants serving large factories, as was shown by Charles W. E. Clarke of the United Engineers & Constructors, Inc. He pointed out that industries and utilities are cooperating in the generation and interchange of electric energy in order to reduce waste in many manufacturing processes.

Higher steam pressures and temperatures are widely used, along with superposition of new turbines on old equipment. Only a few installations have pressures and temperatures which exceed 900 lb. per sq. in. and 850 deg. F., respectively. A number of prominent industrial plants were described to indicate the application of all types of steam turbines to the three steam cycles most commonly employed. Steam-pressure-reducing and desuperheating equipment, as developed for topping units in central stations, is finding new applications in industry. Where large quantities of process steam are needed, many interesting arrangements of modern equipment can be used to reduce the cost of power generation.

The trend in design of boilers is toward larger units, higher steaming rates and more complicated automatic controls to permit utilization of several different kinds of fuel in the same furnace. This presupposes the proper treatment of boiler feedwater, the importance of which was emphasized. Among smaller plants there is a tendency toward the use of a self-contained boiler; also, there has been a revival of semi-outdoor constructions.

Progress is being made toward better utilization of unusual fuels, such as pulverized anthracite culm, lignite, acid sludges, and black liquor, the latter of which is obtained in the process of manufacturing kraft paper.

For a long time engineers have been waiting for an authentic and comprehensive statement from the Detroit Edison Co. on its experience with high temperature steam, so the paper prepared by R. M. Vanduzer, Jr., and Arthur McCutchan, both of that company, created an unusual amount of interest. This paper was in fact a continuation of the one presented in December, 1933, in which the 10,000-kw., 1000 deg. F. turbine installed by The Detroit Edison Co. was described in detail together with the results obtained with various materials used in the construction of a small 1100 deg. F. superheater and piping system. The turbine installation was dismantled in 1937 after 26,453 hr. of service and the 1100 deg. F. equipment has been continued in service for the further testing of materials.

The turbine has demonstrated the practicability of 1000 deg. F. operation. An examination of all principal materials used in the construction of the turbine, piping, and superheater showed that with several exceptions the alloys were in good condition. Measurements made to determine creep disclosed only small amounts.

The results of 1100 deg. F. steam-corrosion tests on 18 steels indicate that the scale formations offer material protection against subsequent steam attack and that the corrosion process is different in steam from that in air. A comparison of creep determinations made on four machined pipe sections—two in service at 380 lb. per sq. in. and 1100 deg. F., and two in service at 380 lb. per sq. in. and 925 deg. F.—and laboratory specimens at the same temperature and stress tend to disprove the theory that total diametral elongation of a pipe subject to internal pressure is materially less than that indicated by tensile-creep tests.

Lubrication

When considering bearing lubrication, the engineer is prone to think of the proper oil film to be maintained as one that will not break while the bear-

ing is operating. Information presented by Walter Claypoole of the Texas Co., however, brings out the importance of considering those very thin films of oil, of the order of 10^{-7} in. thick, that separate bearing surfaces under static conditions. He described methods of depositing these microscopic films and determining static friction, and drew as one of his conclusions from experiments that the oiliness value of a lubricant can best be judged by determining the static rather than by the running coefficient.

In his study of wear in lubrication problems, L. M. Tichvinsky of Westinghouse reported in his findings that boundary or semifluid friction takes place in bearings of practically all rotating machines when they are started or brought to a standstill. This type of friction, lasting a short period of time, is usually accompanied by the wearing of the bearing surface, the journal surface, or both. Wear takes place also in the case of antifriction bearings due to sliding, rolling, or combined sliding and rolling friction. Many other causes, such as misalinement, dirt, or inadequate lubrication, might be responsible for wearing of any type of bearing. He also described the methods employed to obtain the wear resistance of various metals, especially those used in the design of bearings.

"There has been proposed for many years the slogan 'a fair day's work for a fair day's wage.' Therefore industrial managements have more and more needed to face the questions, 'What is a fair wage?' As management, and as employees, individually and collectively, try to face this issue more frankly, they must inevitably turn to adequate job evaluations to help ascertain the facts."—J. E. Walters.

Progress of Oil and Gas Power

As reported by Howard E. Degler of the University of Texas, the past 5 yr. have seen the development of many new lines of lightweight high-speed engines and the improvement of the established heavy-duty types of oil and gas engines. The total installed horsepower has been doubled during this period and the field of application of oil and gas power has been extended enormously. The best performance of modern Diesel engines will go as low as 0.35 lb. of fuel per b.hp.-hr.; in fact, one foreign 5500-hp. engine uses only 0.329 lb. per b.hp.-hr. with 18,000 B.t.u. fuel, corresponding to a thermal efficiency of 41 per cent. Several Diesel aircraft engines have shown the remarkable economy of 0.32 lb. at full load and cruising speed.

One manufacturer has offered to build a 40,000-hp. engine; another engine of 80,000 hp. has been proposed for installation on a ship. Above 1000 b.hp. and below 4000 b.hp. capacity, two-stroke-cycle engines are favored almost three to one; and above 4000 b.hp., this type is used exclusively. At present, there are no four-stroke-cycle, double-acting engines, but of the large two-stroke-cycle units about half are double-acting.

Francis Hodgkinson, Charles T. Main, Gerard Swope and D. S. Jacobus

The gas engine has found new ways to make the most of the numerous pipeline extensions bringing gas fuel to many parts of the country. The effect of the present economic trend upon oil and gas-engine design is shown by the introduction of an increased number of convertible Diesel-gas engines capable of operating on either liquid or gaseous fuels. The gas-injection two-stroke-cycle engine with improved scavenging features is giving as good fuel economy as the four-stroke-cycle types without the loss of any of its inherent advantages of simplicity, compactness, low first cost, and low maintenance.

The future high-speed industrial Diesel engine will probably develop up to 150 b.hp. per cylinder, weigh 10 to 15 lb. per b.hp., run at speeds up to 3000 r.p.m. with piston speeds of 2000 ft. per min., and occupy less than ½ cu. ft. per hp. Present choice between four-stroke-cycle and two-stroke-cycle engines appears to favor the former.

Fluid Meters and Controls

Spurred to activity, no doubt by the work of the special research committee on fluid meters, a whole host of reports dealing with the fascinating subject of metering the flow of fluids were given consideration at this year's meeting. R. M. Van Duzer, Jr., of the Detroit Edison Co., for example, indicated how consideration of the problem of measuring steam flow in the initial stages of the piping design for modern power plants using high steam velocities will result, in nearly all cases, in a more accurate and economical flowmeter installation. He gave examples showing how accurate flow measurements were obtained in the design of equipment for two plants.

Reports were made on investigations made on venturi tubes, long-radius nozzles, orifices, pilot tubes and process controls.

Comprising, as this meeting did, 29 separate technical sessions, at each of which from 2 to 4 papers were presented, the above is but a brief summary of topics and papers discussed which seemed to be of greatest interest to men in the power plant field. The range of topics, however, spread clear across the scientific and industrial field where the mechanical engineer is actively engaged.

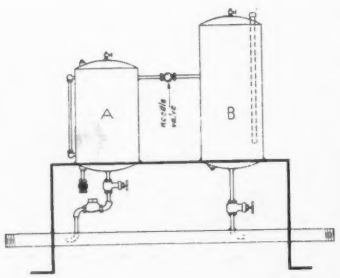
New Equipment

Information that you desire about any equipment will be gladly furnished without obligation. WRITE POWER PLANT ENGINEERING.

Chemical Proportioner

THE MODEL Simplex Feeder has been developed by D. W. Haering & Company, Inc., 3408 W. Monroe St., Chicago, Ill., in response to demand for low priced, accurate, automatic, proportioning equipment. The simplex feeder is specially adapted to proportioning water treatment but may be employed for the proportionate introduction of any average chemical solution into liquid lines.

As shown in the diagram, this feeder is activated by the pressure difference between pitot tubes. Compartment A is filled with Haering piston fluid. Compartment B is filled with chemical solu-

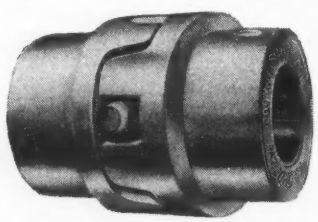


tion. As water flows through the line, a proportionate quantity rises into compartment A displacing the fluid piston across a needle valve control into compartment B, where an equivalent amount of chemical solution is displaced into the line. Compartment B is large enough to prevent loss of the fluid piston under any operating conditions. The unit is recharged by introducing chemical solution into compartment B, forcing the piston fluid back into compartment A.

This unit is assembled completely as indicated in the diagram. Installation of the feeder requires only the connection of the pipe to the main fluid lines either as a by-pass or replacement section.

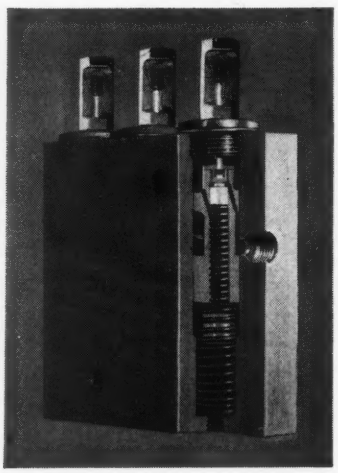
Flexible Coupling

MADE by the Shallcross Co., 48th and Grays Ferry Road, Philadelphia, Pa., the Wood flexible coupling is offered for longer life and more efficient operation of any direct connected equipment. The hardened steel, canvas Bakelite, or rubber replaceable jaws prevent the possibility of replacing coupling halves. Reversible center section providing double wear is obtainable with driving members of fibre, hardened steel, or with load cushion of hardened steel, canvas Bakelite or wear-resisting tire stock rubber.



Lubricating System

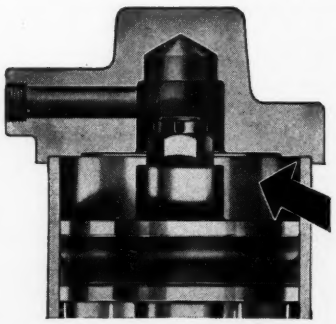
BLAW-KNOX Co., Pittsburgh, Pa., through its Gordon Lubricators Division, announces a new line of grease lubricating equipment offered to users of cranes and auxiliary equipment. It is known as the Model H Lubricating System, and contains a manually operated pumping unit designed for use with the new Model H measuring valve. The pump holds 8 lb. of grease and can be filled by hand,



or by means of a portable grease pump through a fitting provided for that purpose. Double acting pistons, a unique feature for pumps of this type, reduce the time cycle of operation, and a detachable handle is a safety precaution against tampering or excessive operation. Other normal equipment includes a control valve, a grease strainer and a pressure gage. While centrally motivated, each valve is adjustable as to quantity of grease, being capable of feeding from 0 to 0.4 ounce per shot.

Cushioned Air Cylinders

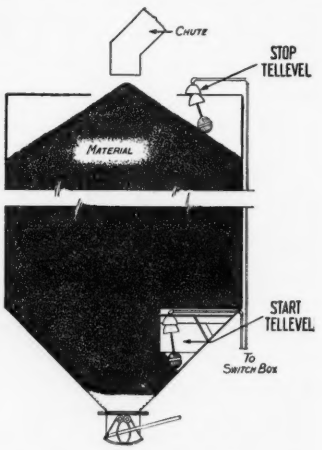
A COMPLETE line of air cylinders with non-adjustable cushion-heads is now available in the same price range as non-cushioned air cylinders. This new development was recently completed by the Galland-Henning Mfg. Co., S. Thirty-first St., Milwaukee, Wis. This new type of Cushioned Air Cylinder eliminates the noisy, destructive, metal-to-metal impact common to non-cushioned cylinders. It is said that cylinder life is greatly prolonged and at the same time, it assures smoother, more efficient oper-



ation and lower maintenance costs for all air powered equipment, benefits definitely proven by exhaustive performance and endurance tests under actual working condtions.

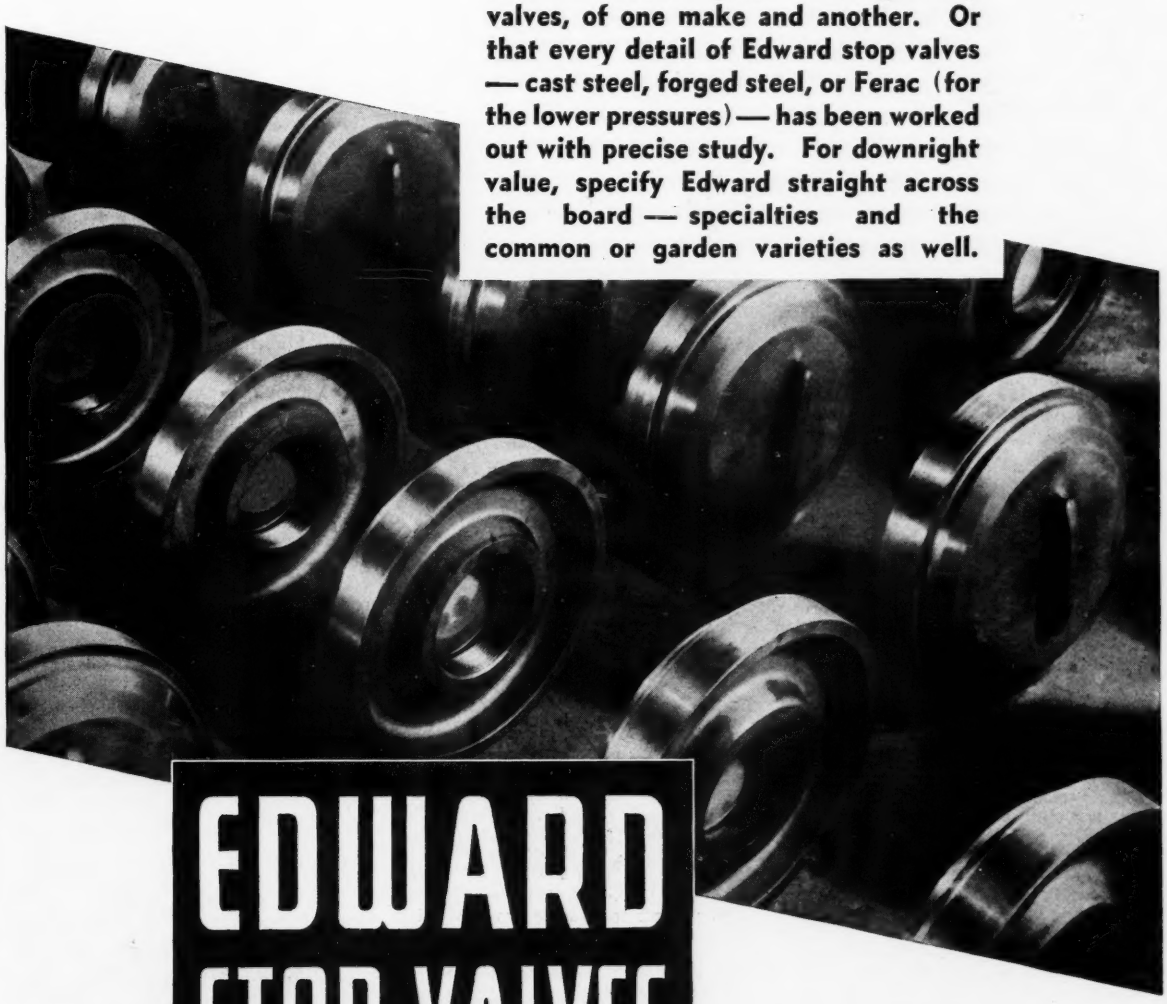
Automatic Storage Control

STEPHENS ADAMSON MFG. Co., Aurora, Ill., announces a new automatic storage control known as the Tellevel. Controlling the level in the bin is accomplished by starting or stopping the con-



veyor or elevators feeding the bin. The Tellevel consists of three mercury switches in series, with a sensitive, cast aluminum housing having a Bakelite sphere extending downward. Housing is suspended from above by conduit pipe which permits Tellevel to swing freely as Bakelite sphere is contacted by material.

NON-RETURN valves, blow-offs, and feed line stop-check valves — these are admittedly down the specialist's alley. And Edward's leadership in these lines is in the record. But not every buyer realizes how much difference there is between globe and angle stop valves, of one make and another. Or that every detail of Edward stop valves — cast steel, forged steel, or Ferac (for the lower pressures) — has been worked out with precise study. For downright value, specify Edward straight across the board — specialties and the common or garden varieties as well.



EDWARD pedigreed forged EValloy disks like these give plus value to EDWARD stop valves.

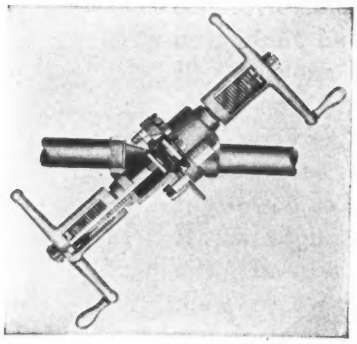
EDWARD STOP VALVES *Excel, too*

The Edward Valve & Manufacturing Co., Inc.

EAST CHICAGO INDIANA

Blow-Off Valve

ANNOUNCED by the Clyde Division, R. W. Cramer & Co., Inc., 67 Irving Place, New York, N. Y., this new valve combines a high pressure flanged union with a double valve in a single unit. Two bonnets securely hold the single stainless steel seat ring in place, and tightness is as-



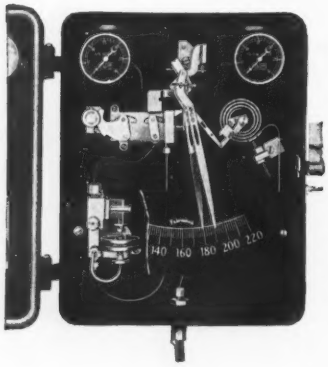
sured by lapping the seat ring to the faces of the bonnet flange. The flanges are set to 45 deg. to axis of flow, closely approximating the flow characteristics of a gate valve. Each half, with its corresponding pipe section, is removable and gives complete accessibility to both valve sections.

The exterior of the bonnet sleeves is threaded, giving a valve lifting thread area of from two to three times the usual amount with an extra deep stuffing box. A non-rotating stem assures low packing friction and long life.

Made in four distinct stock types, these valves meet every requirement in pressures up to 600 lb. Stainless steel trim with stellited seats is used unless otherwise specified.

Indicating Controller

C. J. TAGLIABUE MFG. CO., Brooklyn, N. Y., announces the development of a new Direct-Set Indicating Controller, Model No. 9-TIC for temperature, and Model No. 9-PIC for pressure, designed for ruggedness and operating convenience and presented in a strong weather-proof aluminum case beautifully finished with black enamel and chromium. The distinctive modern style of these new instruments is in pleasing agreement with advanced mechanical construction which give strength and character to any equipment set-up.



These controllers can be supplied in two types: "On-Off" or "Throttling." "On-Off Controller will open the diaphragm valve if the temperature is slightly below the setting point, and will close the valve if the temperature rises slightly above. The Throttling type is identical to the "On-Off" design except for the flapper mechanism. This instrument utilizes an adjustable flapper which provides a convenient and exacting sensitivity adjustment from hair line to 100 per cent throttling range.

The TAG "On-Off" controller and the TAG Throttling controller have the Direct-Set feature. Both the white control pointer and the red setting pointer indicate on the 5½ in. graduated scale, thus offering an ideally clear, direct reading for checking control performance.

Hoists

WHAT is said to be a "fool-proof" hoist has been developed by the Coffing Hoist Co., Danville, Illinois. The newest of its many safety features is the push button control which reverses the action of the hoist. This control also acts as a safety stop; if the worker's hand should slip off the handle while operating, this device automatically locks the handle before it can revolve or cause any damage. Two other separate safety

stops prevent the handle from whirling around and causing injuries to workmen.

A new intermediate locking pawl enables the load to be stopped in locking position at half the length of the regular stroke. In case of excessive overloads the handle bends before any other part of the hoist will give, serving as a warning to prevent chain from breaking or hooks from straightening out and dropping loads. The hoists are available for handling loads from ¾ to 15 tons, and weigh from 14 to 150 pounds.

Small Motor

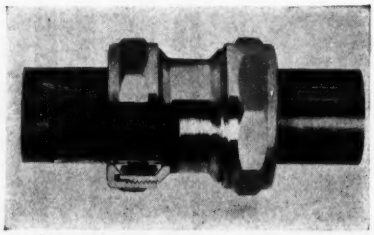
THIS designation covers a new line of motors developed by Barber-Coleman Co., Rockford, Ill., with outputs ranging from 1/200 to 1/40 hp. These motors have exceptionally good speed regulation and quite high efficiency. The operation is very quiet, and they are recommended for sound film projectors, sirocco type blower wheels, and other applications

requiring hard service or good speed characteristics. The shafts are of hardened stainless steel, and the bearings are of the oil-and-graphite impregnated type. Wick type oilers are provided with sufficient capacity for six months' continuous operation. The motors are built in three sizes for different outputs and for different classes of service.

Raybould Couplings

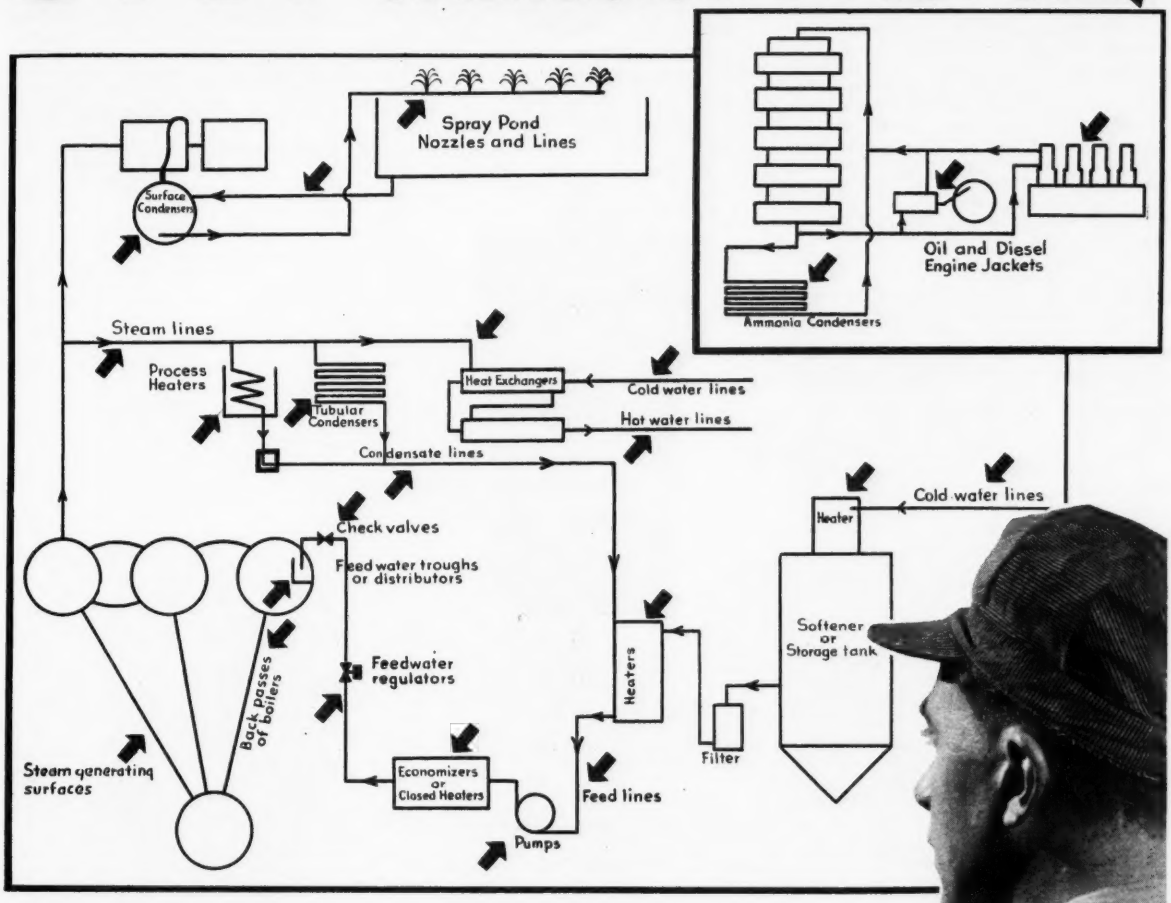
ANNOUNCEMENT has been made of the appointment of the Pittsburgh Equitable Meter Co. of Pittsburgh, Pa., as sole distributor for Raybould couplings and fittings, manufactured by the Raybould Coupling Co., Meadville, Pa.

The Raybould Coupling furnishes a simple and leakproof method of joining plain end pipe. It consists of two resilient compression rings, metal bushed at either end, encased in two flanges or follower rings which bear against a center ring acting as a spacer between the flanges. The compression rings provide the sealing medium while the flanges sustain all the mechanical forces applied in tightening up the coupling. In sizes smaller than 3 in. the flanges consist of two compression nuts and the coupling is fastened by tightening these nuts on a threaded center ring. Larger sizes employ long track head bolts and nuts to draw up the two flanges.



Features claimed for the Raybould coupling are: Designed for high pressures, the pipe being the limiting factor; design provides increased coupling grip on the pipe, sustained over an indefinite period of time; contents of pipe cannot contact with or deteriorate compression ring; joint not affected by normal expansion, contraction or deflection of pipe; small diameter or out-of-round pipe does not affect coupling joint; requires no sizing operations on ends of pipes to maintain close tolerances; requires fewer bolts and only three other major parts to handle in field assembly; low resistance between pipe and coupling eliminates electrolytic action.

STOP SCALE AND CORROSION HERE!



YOU know from experience that scale or corrosion, or both, can cause trouble in many places besides your boiler tubes and drums. But what you may not know is that Nalco offers service to prevent such trouble. Many Nalco customers are now taking advantage of this complete service. The advantages are obvious: (1) One responsibility for your entire plant. (2) Low combined cost. (3) Regular, systematic attention given to all of your problems. We will be glad to give you details on this *complete* treating service. *Write.* NATIONAL ALUMINATE CORPORATION, 6224 W. 66th Place, Chicago, Illinois.

ANY WATER **NALCO SYSTEM** ANY PRESSURE

Inquiries other than domestic, *except those from U. S. Possessions, Canada and Mexico,* should be addressed to ALFLOC LTD., Bush House, Aldwych, London, W. C. 2, Eng. Canadian inquiries should be sent to ALUMINATE CHEMICALS LTD., 372 Bay St., Toronto, Ont.

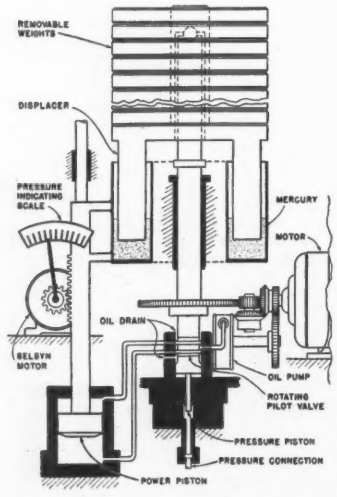
Graphite Lubrication

A SIMPLE, low-cost, solution to the old problem of providing long-life lubrication for small mechanical devices such as locks, fire alarms systems, telephone exchange equipment, news and financial tickers, fans, small motors, clocks, and variable radio parts, etc., has been developed recently by the Acheson Colloids Corp., Port Huron, Mich. The operation consists in dipping parts in a dilute suspension of finely divided "dag" colloidal graphite in water. As the water evaporates, it leaves behind it a thin dry graphite film that provides a practical and efficient method of lubrication over a long period of time.

Prior to dipping the parts in the colloidal graphite suspension, it has been found useful to flush the parts with water-diluted ammonia and then spray them with live steam. This treatment has the double effect of cleaning the surface for ready adhesion of the graphite film and of raising the temperature of the parts to assist in rapid evaporation of the water in which the colloidal graphite is suspended. In some cases the solution may be made in oil instead of water in which case the graphite in its finely divided form has the apparent disadvantage of retaining the oil on the friction surface.

Power Type Pressure Gage

A POWER Type Pressure Gage suitable for the measurement of extremely high pressures and accurate to one-tenth of 1 per cent of the reading, has been developed by Bailey Meter Co., Cleveland, Ohio. This gage as shown diagrammatically provides accurate pressure readings on an indicating scale and may also transmit these readings to indicators and recorders located at distant points.



The pressure to be measured is applied to a small pressure piston which supports a pilot valve and a table loaded with removable weights. A small motor serves to rotate the pressure piston and pilot valve and drives a small oil pump which provides hydraulic pressure for operation of the power piston which in turn moves the mercury cup, the indicating pointer and the Selsyn motor for electrical transmission of readings. Gages operating on this principle have been built for suppressed ranges and extremely high pressures.

Steam Trap

STICKLE STEAM SPECIALTIES Co., Indianapolis, Ind., offers a new steam trap with capacities ranging from 500 to 300 lb. per hr. The valve and seat may be inspected without removing the trap from the line. The trap can be bypassed by giving the nut at the top a

quarter turn. Internal strainer eliminates foreign particles which might clog trap. Rotation of the bucket and valves automatically regrind valves. Internal bypass eliminates air and gases with discharge of condensate which insures maximum efficiency.

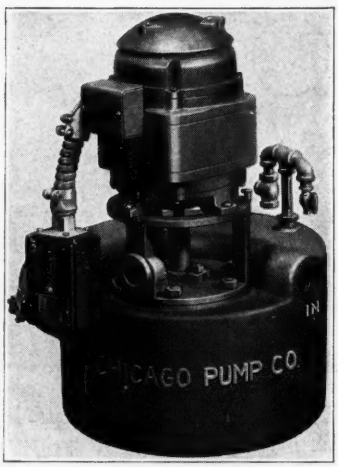
Indicating Micrometer and Comparator

THE GEORGE SCHERR Co., 128 Lafayette St., New York, N. Y., has just introduced a new indicating micrometer and comparator which includes several interesting and important improvements. Among these are the elimination of all gears and racks from the indicator mechanism. Instead, the knife-edge lever type is used, which makes the instrument more accurate, more durable and less subject to loss of precision through constant use. It eliminates the uncertainty of measuring feel since it includes a feature which makes the measuring pressure visible. There is an anvil relieving button which moves back the lower anvil for inserting and removing work. When the work is inserted and the button released, the anvil is pressed against the work by a light pressure return spring. Thus, no matter who does the measuring, the reading is sure to be the same. Measuring feel does not enter into it. All delicate mechanism has been eliminated, resulting in a compact, sturdy instrument that measures in 1/10000 in.

Condensation Pump

A NEW, small condensation pump and receiver has just been placed on the market by the Chicago Pump Co., 2336 W. Wolfram Ave., Chicago, Ill. It is an ideal little unit for heating systems of all kinds where there is a small amount of direct radiation. The pump is used for 500 to 2000 sq. ft. direct radiation and 10 to 45 lb. pressure. The heavy cast-iron receiver is small, and the float has only a short distance to travel; which means that the condensate is returned to the boiler before it has had a chance to cool off.

A single phase, 110/220-v., 60 cycle 1750 r.p.m. repulsion-induction motor is



mounted in a vertical position on top of the receiver, high off the floor. The pump is suspended in the receiver from the motor. The whole assembly, motor and pump, can be lifted out by loosening a few nuts at the top of the receiver. The pump has a bronze casing and rotor and stainless steel shaft. Mounted on the receiver is a heavy duty, enclosed float switch, which is heavy enough to throw the motors across the line. The float switch is actuated by a seamless copper float inside the receiver.

PHOTOSWITCH INCORPORATED, 21 Chestnut St., Cambridge, Mass., has recently made available a low cost method of indicating the production of excessive smoke in power plant stacks. This device operates a bell or other indicating instrument whenever the smoke passing through the furnace flue exceeds a predetermined density. It consists of a light source mounted on one side of the stack and a photoelectric control device on the opposite side. The device is supplied ready to install on any 110 v. circuit.

LUNKENHEIMER

STEEL GLOBE VALVES

With

Bonnet-Thread-Bushing

600 lb. SP-750° F.

1 inch
Fig. 1720
Full-Way
Type

A distinctive design with a nickel alloy bonnet-thread-bushing and stainless steel stem, seat and disc. Bushing is a separate part, highly resistive to wear at extreme temperatures with resultant longer service life.

Disc and seat ring are heat treated to provide great hardness and ground to form a pressure tight seat.

Bonnet-thread-bushing design is available in Screwed and Bolted Bonnet types; full-way or throttling; screwed or flanged.

ESTABLISHED 1862
THE LUNKENHEIMER CO.
"QUALITY"
CINCINNATI, OHIO, U. S. A.
NEW YORK CHICAGO
BOSTON PHILADELPHIA
EXPORT DEPT. 318-322 HUDSON ST., NEW YORK

If you have no copy of List Price Schedule R1 giving new list prices of Lunkenheimer Products, ask your local Lunkenheimer distributor or write The Lunkenheimer Co., Cincinnati, Ohio.

News from the Field

NATIONAL Small Business Men's Association, Akron, Ohio, is undertaking a nation-wide drive for changes in the Wagner Labor Relations Act by circulating petitions to be signed by business and professional men and presented to Congress as proof that the folks back home want changes made in the act. The petition urges equal rights to all parties, employers as well as employees, to be able to initiate proceedings before the Labor Board; protection of employers, employees and their families against coercion or intimidation from any source; review of all evidence by appeal to Federal court; the Labor Board to act only in a judicial capacity; other functions to be taken over by the Department of Labor. Copies of the petition may be had from the Association.

THE RESIGNATION of George A. Burnham as assistant manager of the electrical department, in charge of switchgear sales and engineering division of the Condit Works of the Allis-Chalmers Mfg. Co., Boston, Mass., has just been announced. Mr. Burnham will be succeeded by W. S. Edsall, sales manager. Mr. Burnham is being relieved of his duties at his own request, as he is anxious to devote more time to personal matters and to travel. In the future he will be retained by Allis-Chalmers in a consulting capacity.

EQUIPMENT Standards of ammonia and Freon equipment have just been published by the Refrigerating Machinery Association, Southern Bldg., Washington, D. C., as the first part of a broad standardization program which the Association instituted a year or so ago.

PITTSBURGH PIPING & EQUIPMENT Co., Pittsburgh, Pa., announces the appointment of S. J. Martin as manager, Engineering Department.

THE L. J. WING MFG. CO. with plant in Newark, N. J., and general offices in New York City, has appointed H. E. Birkholz, Gerke Bldg., Cincinnati, in charge of sales in that territory.

AMERICAN Mining Congress will hold its Coal Convention and Exposition in the Music Hall, Cincinnati, Ohio, Apr. 24 to 28, 1939. The exposition will cover mining, preparation, transportation and handling of coal and discussions will cover like **topics.**

ATLAS ASBESTOS CO., LTD., Montreal, has been appointed to represent the Goetze Gasket & Packing Co., Inc., in Canada. This firm will carry a complete stock of all standard types and sizes of Goetze gaskets for immediate shipment.

DR. EDWARD R. WEIDLEIN, Director, Mellon Institute, Pittsburgh, has announced the establishment of an Industrial Fellowship in that institution by the American Air Filter Co., Inc., Louisville, Ky. Dr. Frank F. Rupert has been appointed to the incumbency of the Fellowship.

APPOINTMENT of F. H. Doremus as manager of the General Electric transportation department for the Rocky Mountain district became effective November 15. Mr. Doremus assumes his new duties in addition to those as manager of the industrial department for the Rocky Mountain District. Robert A. Jones, engineer at the Buffalo office, has been appointed assistant engineer for the company in the New York district. W. C. Plumer of the Newark office goes to Buffalo as engineer, and L. F. Stone becomes engineer at the Newark office. The three appointments were effective December 1.

COMBUSTION ENGINEERING CO., INC., has opened a branch office in Birmingham, Ala., under the direction of J. B. Emory as District Manager, assisted by W. E. Johnson. Mr. Emory has been associated with Combustion Engineering Co. for several years in shop management and sales capacities, and Mr. Johnson has long been identified with the sales of this company's equipment in the Birmingham territory. The address is 516 Martin Bldg., Birmingham, Ala.

W. M. CROUCH has been appointed manager of the Glendale, Arizona, branch of the Central Arizona Light & Power Co.

VICTOR A. REDFIELD, 61, president and general manager of the Keystone Public Service Co., died at his home in Oil City, Pa., of a chronic heart ailment on December 5. He had been employed with the City Street Railway Co. and the Keystone Public Service Co., its successor, for a period of 40 yr.

EUGENE E. THOMPSON has resigned as director of the Potomac Electric Power Co., and William E. Lipscomb, president of Barber & Ross, Inc., and the Huntington Terrace Corporation, Washington, D. C., will assume his place on the board, Dr. William McClellan, president of the Potomac Electric Power Co. announces.

HARRY GRENACHER, vice-president in charge of operations for Northern States Power Co., has retired from active participation in the company because of ill health but will continue to act in an advisory capacity. He has been with Northern States and affiliates since 1909. H. C. Cummins, Chicago, formerly vice-president in charge of operations and engineering, with Standard Gas and Electric, will succeed Grenacher.

WILLIAM J. CHALMERS, 86, formerly chairman of the executive Board of Allis-Chalmers, died at his home in Chicago, recently. At different times he had been chairman of the board, vice-president, and treasurer. He retired from active work in 1906, 5 yr. after a Chicago machine shop founded by him had merged with four companies into the nationally-known manufacturing plant of Allis-Chalmers.

HARRY C. ABELL, 69, vice-president of Electric Bond and Share Co., died in a New Orleans hospital November 24 after being ill only a week. He became associated with Electric Bond and Share in 1921.

Previous to his post with the Electric Bond and Share group, Mr. Abell, a native of Winnipeg, Canada, had received two scientific degrees, one from Armour Institute of Technology in 1897 and another from the same institution in 1906, and had served an apprenticeship with the Canadian Pacific Railway.

In addition, Mr. Abell had held the following posts at one time or another: President, National Power & Light Co.; vice-president, New Orleans Public Service, Inc.; chairman, Memphis Street Railway Co.; and president and chairman of West Tennessee Power & Light Co. He had also held board positions with the following companies: Arkansas Power & Light Co., Mississippi Power & Light Co., Carolina Power & Light Co., Tennessee Power & Light Co., Memphis & Lake View Railroad Co. and Southern Gas & Fuel Co. He had been a director of the Chamber of Commerce of the United States and a member of the American Institute of Electrical Engineers, the National Electric Light Association and the Engineering Institute of Canada.

SMOKE PREVENTION Association, Inc., will hold its annual convention in Milwaukee, Wis., at Hotel Schroeder, June 13 to 16, 1939. Besides the technical meetings, an exhibit will display the educational features first shown at the Century of Progress, also commercial exhibits of fuel-burning equipment for securing best economy.

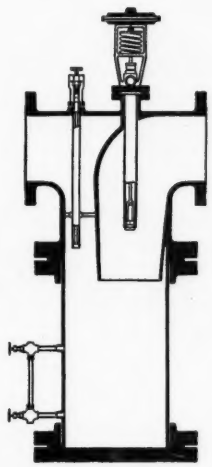
LICENSE has been granted the San Joaquin Light and Power Corp. of California to construct a hydroelectric project of 39,300 hp. on the north fork of San Joaquin River, in the Sierra National Forest. Flowage will include Crane Valley Reservoir and Chilkoot Lake. Power plants of 1300, 24,400, 600, 5250 and 7750 hp. will constitute the system.

Correspondence Courses

THE UNIVERSITY EXTENSION DIVISION, University of Wisconsin, Madison, Wis., announces a correspondence course on Diesel engines available to persons in any state. The instruction fee is $13 in the state; $18 out of the state plus $5 for a text book in either case. This course of 20 assignments is designed especially for those desiring to obtain a good understanding of the construction and operating features of the Diesel engine. It is of a semi-technical nature and suitable for supplementing practical work in the shop, power plant or on the road.

Rutgers University, University Extension Division, New Brunswick, N. J., also announces new outline of their correspondence courses on heating and ventilating, air conditioning and oil burner engineering. The cost of these three courses is $24.00 each. The University notes the growing use of home study courses for supervised groups where a number of employees enroll in a given course, meet in the property of the employer at regular times with a company engineer or other leader to discuss the current lesson or carry on actual recitation by correspondence. The public utility companies have been the pioneers in this field beginning with the Rutgers University course in the manufacture, distribution and utilization of gas for all grades of its operating personnel, and following this up for selected groups with the University's courses in heating and ventilating and air conditioning.

The COPES DESUPERHEATER



Accurate for total or partial desuperheating, on steam from 212 to 1100 degrees F.

Dependable for all flows, regardless of any change in the temperature of the superheated steam entering the unit.

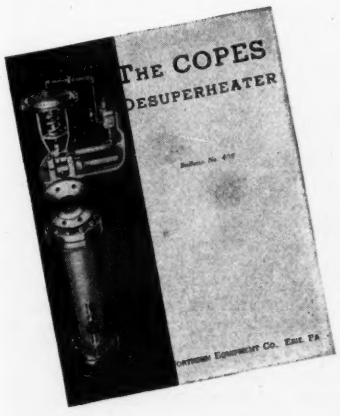
Water correctly proportioned to steam at all times because cooling water is controlled at the spray nozzle—not by any outside control valve.

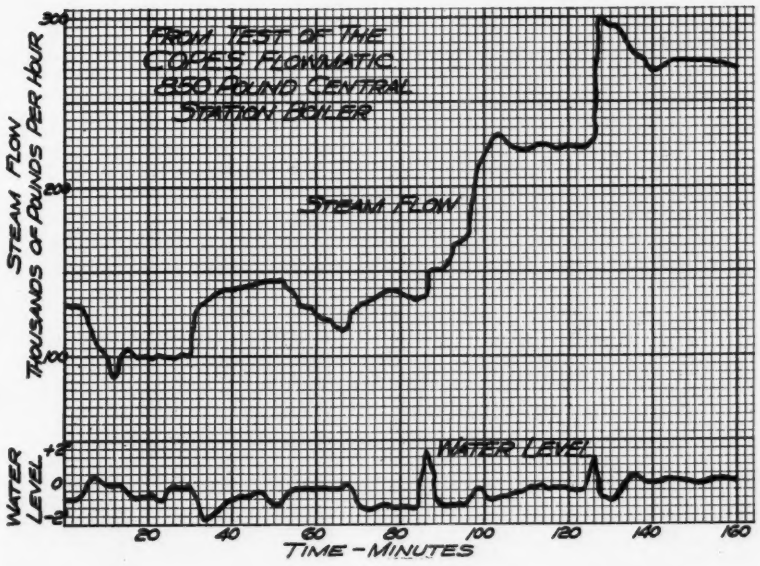
Final temperature held within close limits, because cooling water is completely atomized.

A self-contained unit, with a simple external adjustment for temperatures and sensitivity.

For complete information—

Write for Bulletin 405





Troubled with Carry-Over?

No matter how rapid your load swings, the COPES Flowmatic Regulator will hold your boiler water level within close, safe limits. This will greatly reduce the possibility of water carry-over, and thus help you avoid excessive maintenance on superheaters and prime movers. For the COPES Flowmatic is easily adjusted—no "experts" needed—to give you exactly the right water level characteristic for safest, most economical operation of your boilers. Write—on your letterhead—for descriptive Bulletin 409-B.

NORTHERN EQUIPMENT CO., 112 GROVE DRIVE, ERIE, PA.

Feed Water Regulators, Pump Governors, Differential Valves
Liquid Level Controls, Reducing Valves and Desuperheaters

BRANCH PLANTS IN CANADA, ENGLAND, FRANCE, GERMANY, AUSTRIA AND ITALY . . . . REPRESENTATIVES EVERYWHERE

Get closer level control with the

COPES

FEEDS BOILER ACCORDING TO STEAM FLOW•AUTOMATICALLY

FLOWMATIC

★ REGULATOR

St. Lawrence Canal Opposed

COAL DIVISION of the American Mining Congress, meeting in Pittsburgh, December 2 and 3, with a large attendance of leading coal operators and manufacturers of mining machinery, declared opposition to the proposed treaty with Canada for the building of a Great Lakes-St. Lawrence River Waterway; submitting that a channel 27 ft. in depth to the ocean and an immense hydroelectric power development along the St. Lawrence River, is uneconomic and unsound; that this proposal will greatly increase the present excessive tax load on industry; will increase the cost of our basic fuel, coal; will permit importations of coal from the Black Sea ports of Russia and other low-living-standards countries; will permit heavy importations of low-cost petroleum from Venezuela and Mexico; through unneeded development of hydroelectric power will displace millions of tons of coal production and take work away from thousands of coal miners and railroad workers; and will seriously cripple our railroads, the plight of which is today one of our gravest national problems. The heavy diversion of water to the St. Lawrence River would also seriously harm the facilities of the Mississippi Valley waterways for the carrying of coal and other freight.

N. T. Chadderdon

ANNOUNCEMENT was made at a recent banquet of Fisher Governor Co. employees at Marshalltown, Ia., of the election of N. T. Chadderdon as president and treasurer of the Company to succeed the late Jasper H. Fisher. Mr. Chadderdon has been with the organization since 1931, and for several years has been secretary-treasurer. The principal address of the evening was made by Guy L. Reed, vice-president of Harris Trust & Savings Bank of Chicago, Mr. Reed being a boyhood friend of Mr. Chadderdon and a college mate at University of Nebraska.

N. T. Chadderdon

Taxes Survey

IN ORDER to get real facts as to the tax situation, what industries carry heaviest burdens and the amount of Federal, State and Local taxes, Dun & Bradstreet, Inc., are making a nation-wide survey. Business trends will also be surveyed to determine whether business is going ahead or backwards. Some 2,000,000 questionnaires will be sent out January 1 to every concern on the Dun & Bradstreet list, questions having been prepared by economists, tax experts and business men to give maximum information with least effort to coöperators.

Summary of the analysis will be published by POWER PLANT ENGINEERING as soon as available and readers are urged to coöperate by filling out the blanks as soon as possible after receipt, since prompt availability and analysis of data are important in giving it value. Detailed analysis of major problems and divisions will follow as rapidly as they can be completed.

Power Equipment on Parade

WITH every display space on all three floors of the Grand Central Palace in New York City occupied during the week of December 5 to 10, the 13th National Power Show gave visitors a definite impression that industrial prosperity is on the increase. Many of the new designs and devices talked about 2 yr. ago with fingers crossed because of their experimental stage were boldly on display this year with a proud record of accomplishment back of them. It was particularly noticeable, however, that this show was making its appeal to the industrial power user as distinguished from former shows that were designed to interest principally those having to do with power generation.

In attendance, this year's show reached 42,000, and companies reported an unusual buying interest with many sales made and possibilities inaugurated in their booths at the show.

General View of 13th National Power Show

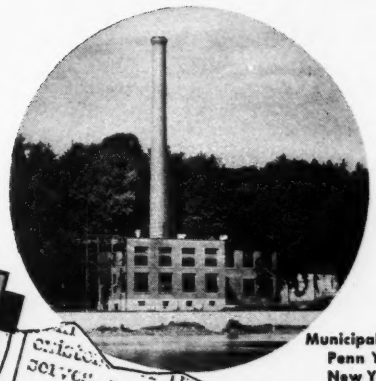
For the first time a water cooled underfeed stoker was on display. The exhibit consisted of two full-sized retorts of an existing installation which has been outstandingly successful. The application of water-cooling to the top surface of the stoker was clearly indicated. The tubes providing this water-cooling were supplied with water from the boiler circulation by the same methods employed in the design of water walls. The stoker was operated by means of an electro-hydraulic drive capable of adjustment throughout a coal feeding range of more than 20 to 1. Sections of armored water walls were set up to illustrate the proper application of water cooling in a stoker-fired furnace.

Insulating cement, rock wool blankets, pipe covering, block and other heat insulation materials were also exhibited. Non-spalling refractory constructions were on display which included suspended air cooled walls that are easily applied to existing constructions; suspended arches, built in any form without recourse to special shapes; and battery wall constructions.

In one of the booths a valve that separates water and solids from steam and compressed air as they flow through a self-contained separating unit inside the valve was shown in cross-section. This equipment, because of its efficiency and flexibility of design, permits large separating capacity to be built into limited space.

PENN YAN Pays Dividends

DETROIT STOKERS



Municipal Plant
Penn Yan,
New York

Municipal Plant Paying Dividend in Free Lights

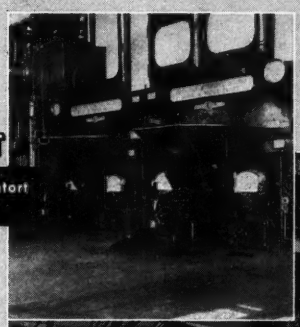
PENN YAN, N. Y., July 30 — (A. P.) — Penn Yan consumers of electricity found their July bills paid in full today, a dividend of a month's free current from the municipally owned and operated plant.

H. Allen Wagener, president of the Municipal Board which manages the plant, said the bills would total about $5,500, divided among 2,232 consumers.

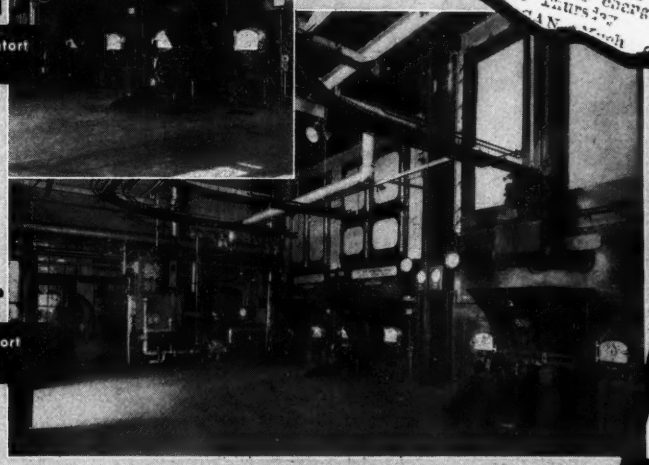
This gift brings to a total of $52,000 the dividends in free current that the board has passed on to users during an eight-year period.

1ST CONTRACT
Detroit Single Retort Stoker—1927

2ND CONTRACT
Detroit Double Retort Stoker—1929



3RD CONTRACT
Detroit Triple Retort Stoker—1932



Detroit Stokers in Municipal Plant, Penn Yan, New York

For LOW STEAM COST DETROIT STOKERS

Write for Bulletin 524

DETROIT STOKER COMPANY

Sales & Engineering Offices • General Motors Building • Detroit, Michigan
Main Office and Works • Monroe, Michigan • Built in Canada at London, Ont.
District Offices in Principal Cities

Novel features are incorporated in the design of a new blowoff valve that combines a high pressure flanged union with a double valve in a single unit. Also a compressor valve machined from solid alloy steel forgings was presented. In this assembly, all parts such as valve seats, guards, valve plates and springs are heat-treated. Passages in the valves are smoothly machined for reduction of flow resistances. Relative to ringplate valves, the claim was made that for pressures up to 400 lb., construction from stainless steel, with oil-hardening, is new to most engineers and designers.

Newly developed lift-plug valves were exhibited in straightway, three-way and four-way types. Elimination of operating difficulties under temperatures reaching 1000 deg. F., and pressures up to 1500 lb. is claimed. In another exhibit working models of self-contained, electrically operated valves for accurate temperature control were featured. A glass bodied steam trap in actual operation with an accompanying diagram to explain its operation won visitor attention.

In the field of transmission, rope drives included those embodying a concave side wall, latex cording, and bias-cut fabric cover. Another manufacturer displayed silent and roller chain drives, flexible couplings, over-running clutches, and a variable speed control unit which was on display for the first time in the East. Also on display was a new line of variable speed motor pulleys for providing infinitely adjustable speed control from any standard, constant speed motor.

Sectionalized models and working demonstrations of equipment featured that part of the exposition devoted to valves and fittings. A complete power plant was set up with boiler, reducing valve, load, trap, open receiver and pump, showing the trap under glass in actual operation. The display consisted of an electrically operated boiler completely enclosed, generating steam at about 20 to 22 lb. pressure, reducing it through a reducing valve to 10 lb. pressure, and condensing about 8 lb. an hour. The condensate flowed through a trap having glass on both sides, and returned to the trap from an open receiver from which a float operated motor driven pump returned it to the boiler.

Semi-metallic packings and specialty packings, some of which are specially designed to resist oil conditions where rubber heretofore has proven unsatisfactory were shown.

A large scale model of a turbine generator, including condensers and power plant pumps, was displayed. Attention also was attracted to modern electric motors, controls, and speed changers for revolutionizing industrial drives, boiler feed pumps, and boiler feedwater treatment.

Instruments and controls, featuring new developments and unique applications, attracted wide attention. Working models of control panels demonstrated the latest methods of completely automatic control by means of electrically transmitted impulses. A solenoid motor control panel for high speed milling machines was shown in operation. Magnetic liquid level gages for atmospheric and pressure tanks up to 400 lb. pressure also were shown. The magnetic action together with the use of a brass forged head makes possible an absolutely tight head.

Another exhibit contained a complete line of manual, semi-automatic and automatic a.c. and d.c. motor starters, speed regulators and accessories. High and low voltage capacitors of neat appearance and flexibility for all mounting conditions also were shown. Other interesting items included electrical switches, boiler meters, automatic combustion control units, feedwater controls, fluid meters, draft gages, counting machines and watchmen's clock systems.

One exhibitor of steam traps demonstrated his products by means of a complete power plant assembly, including boiler, reducing valve, load, trap, open receiver and pump. The display consisted of an electrically operated boiler completely enclosed, generating steam at about 20 to 22 lb. pressure, reducing it through a reducing valve to 10 lb. pressure, condensing about 8 lb. an hour. The condensate flowed through the trap from an open receiver from which a float-operated, motor-driven pump returned it to the boiler.

Manufacturers of asbestos-cement piping emphasized the strength, light weight, smooth bore, durability, easy-jointing, and low maintenance costs of their products. Cross-cut pipe sections were on display.

Power driven machines and tools were shown in great numbers. One new development was a contour machine of unusual versatility and sturdiness, with a variable speed ranging from 50 to 1500 ft. per min. Infinite speed adjustment can be made at any point by means of an ingenious regulating mechanism. The same exhibit demonstrated a process that slices metals as well as other materials to the shapes desired, with elimination of worthless chips. In another exhibit, a new model, horizontal or vertical, abrasive belt, surfacing and polishing machine was displayed. This equipment is furnished with a special type of ball bearing, and it is adjustable vertically or horizontally without loss of time. A complete line of newly designed milling machines, off-hand lathes, and wire forming machines was introduced; also featured with a high-speed, precision jig borer.

Pipe and bolt cutting and threading machines emphasized many new developments. A modernized and complete line of hand tools and machines to cut and thread ⅛-in. to 12-in. material stressed time-saving advantages. Low-price, portable pipe and bolt machines also were shown. Factory engineers were on hand to demonstrate. An animated display of screws and bolts attracted wide attention, as did operating exhibits of improved wrenches.

One of the most spectacular installations at the Power Show was a unique rubber conveyor belt system that rose from the floor to the ceiling in the open court of Grand Central Palace. The system utilizes a large reinforced rubber "moving pipe line." It is split longitudinally throughout its length and is caused to open at stations for the purpose of receiving and discharging its load. In this tube are carried wet or dry materials, vertically or obliquely without disturbing the original form of the materials handled. Built-in separators prevent bunching.

Oil and graphite lubricants were the subject of several interestingly prepared exhibits. A miniature working model of a factory conveyed the idea of smooth operation by means of oil lubricants. Mechanical packings were represented by one display of a grease and oil retainer which has been developed for a wide variety of operating conditions on revolving shafts. Flax, asbestos, rubber, semi-metallic and specialty packings were displayed. A full line of abrasives also was presented.

For the Engineer's Library

Any Catalogs that you wish will be gladly sent. Write Power Plant Engineering.

Prime Movers

Marine Steam Turbines of 3000 hp. for 400 lb. and 750 deg. F. are described in the Log of Trials of S.S. Pan-Maryland. The turbines are compound, high-pressure at 6000 rpm., low-pressure at 5000 rpm., with double-reduction gears in a single casing. The Log is available from De Laval Steam Turbine Co., Trenton, N. J.

Stoker—Catalog No. 11 describes the unique features of Stowe Stoker and is complete with illustrations of installations, engineering diagrams, case histories, including heat balances. The Johnston & Jennings Co., Cleveland, Ohio.

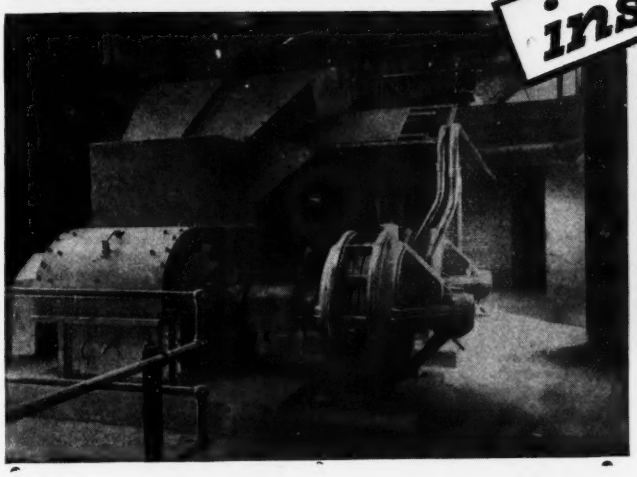
Diesel Engine use of Nickel Alloy Steels is illustrated, also the use of such steels in roller chain over a period of 40 yr. by Whitney Chain & Mfg. Co., in December Nickel Steel Topics, issued by International Nickel Co., 67 Wall St., New York city.

Valves

Valves for Hydraulic Turbines are shown and described in the quarterly issued by Baldwin-Southwark Corp., Philadelphia, Pa. Other topics are Fatigue Testing of Automobile Parts, Presses for Forming Plastics, Testing of Materials as carried out at Cornell University.

installs

AMERICAN RING CRUSHERS



Another nationally-known plant turns to "AMERICAN" to cut crushing costs . . . .

The "AMERICAN" *Splits* Coal

The reversible shredder ring—found only in AMERICAN RING CRUSHERS—is the reason why coal is *split* rather than crushed and which thereby insures absolutely uniform sizing for the purpose intended. This ring—of manganese steel—withstands long hard usage and in conjunction with an adjustable grinding plate affords a simple method of obtaining properly sized coal.

IT is still too early to have actual performance figures of this recent "American" installation, but it is not too early to predict that the West Penn Power Company's experience will parallel that of many other leading plants that have turned to "American" for savings in coal crushing.

In hundreds of installations, better coal sizing, with American Ring Crushers is obtained with savings in fuel cost of from 2½ to 8%. Furthermore crushing costs, including operating and fixed charges, average less than 2 cents per ton.

Whether you require properly sized coal for stoker or pulverized fuel firing, it will pay you to get all the details concerning "Americans."

AMERICAN PULVERIZER COMPANY 1429 Macklind Avenue St. Louis, Missouri

ORIGINATORS AND MANUFACTURERS OF RING CRUSHERS AND PULVERIZERS

Valve Values for December treats of Blow-off Valve Materials, Probing Valves for Defects by Roentgen Rays, Study of Corrosion of Steels, Valves in the Oil Fields, Types of Non-return Valves, Modern Stop Valves. Issued by The Edward Valve & Mfg. Co., Inc., E. Chicago, Ind.

Clyde Valves are illustrated and described in a new bulletin giving sizes, application and price list. Clyde Division, R. W. Cramer & Co., Inc., 67 Irving Place, New York, N. Y.

Philadelphia Limitorque Valve Operator is illustrated and described in a new 4-page bulletin giving specifications and dimensions. Philadelphia Gear Works, Erie Ave. and G St., Philadelphia, Pa.

Lubrication

Diesel Engine Oils are described in a new bulletin recently issued by E. F. Houghton & Co., 240 W. Somerset St., Philadelphia, Pa.

Universal Inventions is a 330 page book published by the Universal Oil Products Co., 310 South Michigan Ave., Chicago, Ill., listing some 1100 patents owned by the company and used in connection with oil refining. Descriptions are as they appear in the Patent Office Gazette.

Lubrication. Fundamentals of Automotive Lubrication are fully and interestingly discussed and illustrated in a 52-p. manual. The factors which enter into the problem of lubrication are made clear and a series of cartoons, descriptions and comments makes clear how the problem should be solved. Why and when oil wears out, what is reasonable oil consumption, driving of cars to secure best economy and maintenance, causes of excessive deterioration are some of the subjects treated. The book, which is well worth careful reading, is issued by Shell Petroleum Corp., St. Louis, Mo.

Materials

Cement—A revised and enlarged edition of the Smooth-On Handbook describes all Smooth-On Metal Cements and products. Smooth-On Mfg. Co., Jersey City, N. J.

Creep Stress Data on the various Croloys and other materials are available on a handy letter size card to those interested in the design of tubular equipment for high-temperature, high-pressure service. The data were obtained, in nearly every case, by tests on commercial materials—the creep tests averaging 3000 hr. duration. The Babcock & Wilcox Tube Co., Beaver Falls, Pa.

Refractory Cement. Hytempite for bonding refractory brick and shapes, for lining furnace walls and baffles; its properties and methods of using are described in Catalog H. G. 501, issued by Quigley Co., Inc., 56 W. 45th St., New York city.

Metal Alloys—The Development and Research Division of The International Nickel Co., Inc., 67 Wall St., New York, N. Y., has just published Bulletin T-9, consisting of 15 pages dealing with the engineering properties of K Monel, a corrosion resistant wrought alloy of nickel, copper and aluminum.

Fibre and Rubber Insulation. National Electrical Manufacturers Association announces the release of a new standard entitled NEMA Standards for Vulcanized Fibre, Publication No. 38-51, containing information on standard grades of vulcanized fibre; standard colors; dimensions of sheets, blocks, rods and tubes, and mechanical and electrical tests for all standard grades. This publication supersedes a previous edition numbered 35-29 which was published in 1935.

The Association has also just published the findings of its Rubber-Covered Building Wire Section on the Current-carrying capacity of Rubber-insulated Building Wire, covering maximum operating temperatures; current carrying capacity in amperes for conductors of sizes 14 B.w.g. to 2,000,000 cir. mils, inclusive, for each of the three grades of insulation and for various conditions of installation; a guide for proper current-carrying capacity for 18 wiring methods listed in the National Electrical Code; a.c. resistance of conductors for all sizes of wire up to 2,000,000 cir. mils, expressed as a ratio of a.c. to d.c. resistance; formula for current carrying capacity calulations.

Copies of either publication may be obtained from the National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y., for 25 cents a copy.

Electrical Equipment

Electric Welding — Procedures for producing all types of welds in mild steel, for welding all metals used to any extent industrially and for applying surfacing metal to meet any type of wear-action in service, are given in a new bulletin recently issued by The Lincoln Electric Co., Cleveland, Ohio.

CSP Power Transformers, designed to provide a better standard service through a lower first cost installation than the equivalent rating in a conventional substation and through provisions for protection and continuity of service, are described in a 16-page illustrated booklet published by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Instruments

Instruments — Bulletin No. 1178 completely illustrates and describes TAG Recorders and Recorder-Controllers. C. J. Tagliabue Mfg. Co., Brooklyn, N. Y.

Gauge—Bulletin Nine-C, a single sheet describes the inclined velocity gage sets for pitot tubes, applicable to the measurement velocities in pipe line. The Ellison Gauge Co., Chicago, Ill.

Neon Illuminator is illustrated and described in a new folder showing how to make reading water gages easier and accurate. Wright Austin Co., 315 W. Woodridge St., Detroit, Mich.

Conveying Equipment

Boiler Plant Coal Handling Equipment—Bulletin No. 83, a 48-page catalog under this title describes Bartlett-Snow central station coal handling equipment of standard and special designs of large capacity hoppers, feeders, belt conveyors, bunkers, galleries, and skip hoists. The book also describes the standardized equipmnt developed for boiler plants from 1000 to 5000 hp. C. O. Bartlett & Snow Co., Cleveland, Ohio.

Pipe-Line or Pneumatic Conveyors are illustrated and described in Catalog No. 18 which has just been issued by Hahn Engineering Co., 30 Church St., New York, N. Y.

Screw Conveyor—A 64-page catalog under this title contains information on screw conveyor installations, selection of screw conveyors, capacity charts, specifications. It also contains a complete cataloging of REX cast and REX Salem type elevator buckets. Chain Belt Co., Milwaukee, Wis.

Wire

Strand Data Book. Publication E. D. 1686, an 8-page illustrated data booklet contains tabular information on the physical properties of guy strand, some notes on installation practices and a convenient graphical method of determining the required strength of guys. Copperweld Steel Co., Glassport, Pa.

Gilmore Wire Rope Division — A new bulletin announces the completion of the Gilmore Wire Rope Division of the Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Pumps

High-pressure pumps, 3-stage for 1200 lb., as used in the Republic Steel Corp. new strip mill are described in a bulletin issued by De Laval Steam Turbine Co., Trenton, N. J.

Pumps—A new bulletin illustrates and describes the growth and history of Goulds Pumps, Inc., which is now celebrating its 90th anniversary. Goulds Pumps, Inc., Seneca Falls, N. Y.

Oil Pumps—Bulletin W-475-M2 is a four page folder devoted to the construction of Worthington rotary pumps Type GEC built to unload all types of fluid in capacities from 500 to 5000 g.p.m., viscosities to 500,000 s.s.u. and pressures up to 150 lb. per sq. in. Worthington Pump and Machinery Corp., Harrison, N. J.

Miscellaneous

Water Cooling Unit—Bulletin 900, a four-page leaflet in color, describes the standardized portable water cooling units, built in four sizes, especially adapted to oil field and portable engine use. The Marley Co., Kansas City, Kan.

Crane Research Laboratories — A new 48-page book with plastic binding —under this title well illustrated with a number of photographs—describes completely the Crane Co.'s facilities for research work. Crane Co., 836 S. Michigan Ave., Chicago, Ill.

READING-PRATT & CADY

FOR HIGH PRESSURE AND HIGH TEMPERATURE SERVICE

PRESSURES up to 1500 lbs.

TEMPERATURES to 950° F.

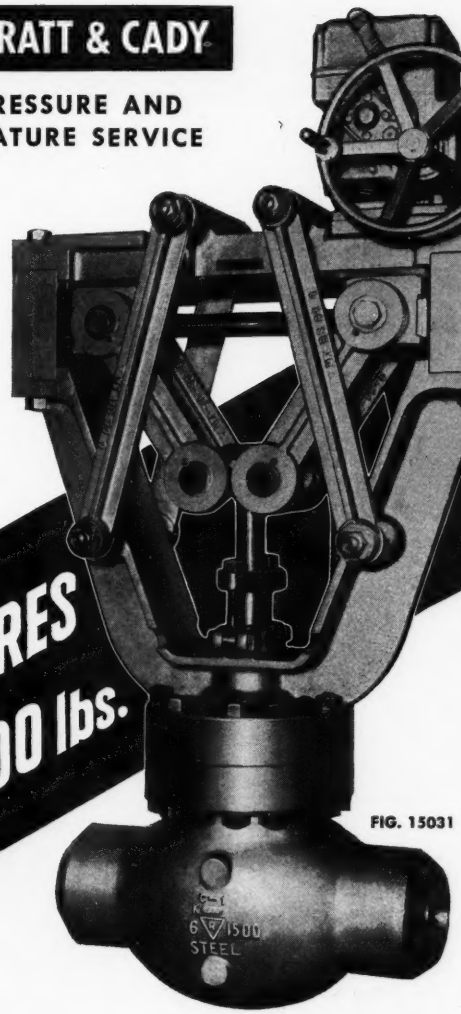


FIG. 15031

MOTOR-DRIVEN TOGGLE-OPERATED —IDEAL FOR GLOBE VALVE DESIGN

Another Stride Toward Lower K W Production Costs—due to *combined* specifications of this new globe valve.

Body of carbon molybdenum cast steel. Spindle of stainless steel. Stellite surfaced disc and welded-in seat ring. For 1500 lb. service up to 950°F. Toggle operation because the high ratio of mechanical advantage of toggle design increases as the closing position is approached—when a closing globe valve meets its greatest resistance. Motor operated for efficiency and convenience.

You will be interested in complete data. Write for it. Sound engineering is backed by extensive steel valve and fitting plants and by brass and iron valve shops established since 1878.

BUY ACCO QUALITY *in Reading-Pratt & Cady Valves, Page Welding Electrodes, TRU-LAY Preformed Wire Rope, American Chains, Wright Hoists and Campbell Cutting Machines.*

READING-PRATT & CADY DIVISION
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AMERICAN CHAIN & CABLE COMPANY, Inc.

AMERICAN CHAIN DIVISION • AMERICAN CABLE DIVISION • ANDREW C. CAMPBELL DIVISION • FORD CHAIN BLOCK DIVISION • HAZARD WIRE ROPE DIVISION • HIGHLAND IRON AND STEEL DIVISION • MANLEY MANUFACTURING DIVISION • OWEN SILENT SPRING COMPANY, INC. • PAGE STEEL AND WIRE DIVISION • READING-PRATT & CADY DIVISION • READING STEEL CASTING DIVISION • WRIGHT MANUFACTURING DIVISION • IN CANADA: DOMINION CHAIN COMPANY, LTD. • IN ENGLAND: BRITISH WIRE PRODUCTS, LTD. • THE PARSONS CHAIN COMPANY, LTD. • *In Business for Your Safety*

Industrial Rubber Hose—A compact data book, containing valuable information on the selection, care and use of industrial rubber hose lists nearly sixty types of rubber hose used by indusery today; defines fundamental terms and explains their relationship to hose structures. New York Belting & Packing Co., Passaic, N. J.

Condenser Cleaners—4-page Bulletin W-200-B4 describing a hydraulic tube washer for surface condensers which can be used without removing the condenser from service and while it is in full operation. Worthington Pump & Machinery Corp., Harrison, N. J.

Water Conditioning and Control—Five new bulletins which vary in subject and treatment have just been released. Bulletin 2118, a non-technical treatise, gives the applications and operating principles of Permutit's new carbonaceous zeolite, Zeo-Karb. The Rate of Flow Indicator is described in Bulletin 2111, giving specifications. Permutit Operating Cabinets and Tables is the title of Bulletin 2154 which outlines four types of master valve control for water softeners and filters. The Multiport Valve is the topic of discussion in Bulletin 2153. Permutit Degasifier, a new development in forced draft operation, is described in Bulletin 2142. The Permutit Co., 330 West 42nd St., New York, N. Y.

New Engineering Books

Refrigerating Data Book—Fourth edition of the Refrigerating Data Book, published by The American Society of Refrigerating Engineers, New York City. Carries the format and arrangement of its predecessors and is greatly improved in content. A. B. Stickney, engineer with Armour and Co., Chicago, is the chairman on the Data Book Committee which includes, J. C. Bergdoll, Arthur W. Ewell, George E. Hulse, V. L. Maleev, L. E. Philipp, C. D. Mackey, Charles H. Roe, Gardner Poole, F. O. Urban and George E. Wallis. New departures include specification tables to show dimensions, capacities and other facts about existing equipment. The book will contain no section on applications, but the parts dealing with basic data and equipment for producing refrigeration have been expanded, applications of refrigeration to be covered in a second volume of the book to appear two years hence.

There are 50 chapters, divided into eight parts with thumb tabs and a table of contents of each part; also elaborate general index. The parts cover Refrigeration, Refrigerants, Heat Flow and Insulation, Air Conditioning, Foods, Domestic and Commercial Machinery, Industrial Machinery, Controls and Power. 6 by 9 in. Cloth. Price, $4 in the United States.

Steam and Gas Engineering. By Thomas E. Butterfield, Burgess H. Jennings and Alexander W. Luce. Published by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y. Size 6½ by 9½ in., cloth bound, 473 pp. Price $4.50.

Through three editions the arrangement and content of this book have been improved until it is probably the most concise and comprehensive text now available on the fundamentals of contemporary steam and gas engineering. The authors are professors or associate professors at Lehigh University and the text is primarily a college text book yet, because of its logical arrangement, direct approach and simple presentation, it is well adapted for home study by those with the background necessary for a serious approach to a subject which forms the backbone of power generation.

Due to the increasing importance of high pressure steam, this was emphasized in the second edition and efficiency heat balance and thermal calculations received increased attention. Performance data on stokers, boilers, turbine, steam and gas engines were included. In the third edition, two additional chapters on internal combustion engines have been added and the steam data brought up to date by substituting the New Keenan & Keyes data and more recent extract and reference material. In the chapter on Boiler Plant Auxiliary Apparatus, the new Rivesville Station has been used as an example of combustion, feedwater and superheat control. The book is divided into 25 chapters covering all phases of steam, internal combustion engines and refrigeration practice.

Design of Switchhouses for Generating Stations and Transmission Substations. Publication No. F5, published June, 1938, by The Edison Electric Institute. Price 40c to members of the Institute and their employes, $1.00 to non-members in the U. S. A.

This 22 page booklet is a report of the Apparatus and Design Division of the Electrical Equipment Committee of the Edison Electric Institute. It presents information on the basic design of switchhouses operating at voltages between 11 kv. and 24 kv. Specifically, it covers reports on 11 operating companies, covering 12 generating stations and one transmission substation. Comments of a general character from 5 other companies are included.

Air Conditioning for Comfort, by Samuel R. Lewis, third edition 1938. 285 pp., 6 by 9 in., clothbound. Published by Keeney Publishing Co., 6 N. Michigan Ave., Chicago, Ill. Price, $2.50.

This new edition of Lewis' book has been completely rewritten, revised and enlarged and embodies the experience resulting from use of the two earlier editions in almost daily practice and by students in many schools. It will be found valuable as a text for school and home study use, as well as a reference for the contractor, engineer, architect, and owner or prospective the motion picture art, it is of course owner of an air conditioning system.

Extended use of the book as a school text has demonstrated that the near-enough approximations in examples due to use of a slide rule, do not satisfy all requirements, and these approximations have been eliminated. In the examples of psychrometric computations, both the tables and the chart are applied. This is done as an attempt to render both devices thoroughly understandable.

The book is divided into twenty chapters and gives a comprehensive treatment of the entire subject in a manner that is easily comprehended.

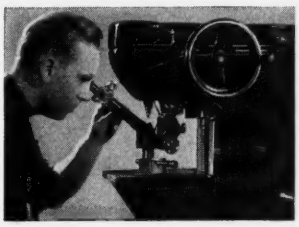
Air Conditioning, Heating and Ventilating. By J. Ralph Dalzell and Charles L. Hubbard. Published by the American Technical Society, Drexel Ave. at 58th St., Chicago, Ill. Size 5½ by 8½ in., 592 pp.; cloth bound. Price $4.

This is a clearly written, well illustrated and thoroughly practical book which fits in well with the other new books on air conditioning recently published by this company. It covers steam, hot water, vapor, vacuum and forced air heating systems, split systems for heating and ventilating, and air conditioning for all types of buildings. Principles and calculations have been simplified and the book is filled with illustrated examples worked out in detail. Where no standard practice has yet been established—several different methods are presented. The examples are representative of actual jobs and many manufacturers' tables have been included in order to make the text practicable and usable without reference to a large number of catalogs. Although these tables and the many illustrations cover actual equipment, no recommendations are made as to the make of equipment which should be used. Practice problems on typical specifications are scattered throughout the book, although one chapter of 16 pages is devoted entirely to a detailed calculation of typical examples commonly found in practice and representing the procedures of engineers in making actual calculations.

Motion Picture Sound Engineering. First Edition. 547 Pages, 6 by 9, cloth, illustrated. D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y. 1938. Price $6.50.

This book is straight from the workshops of the greatest studios in Hollywood. It presents complete and authentic information on the most up to date technique in motion picture sound engineering. The volume consists of a series of lectures presented to the classes enrolled in the courses in Sound Engineering given by the Research Council of the Academy of Motion Picture Arts and Sciences at Hollywood and it provides a complete coverage of the entire field of motion picture sound engineering. Leading engineers in the great companies explain every phase of the subject clearly and thoroughly—presenting every detail of apparatus and its arrangement with hundreds of diagrams, tables, charts, and graphs. It is simply written and gives the necessary background in physics, acoustics, optics and electricity. While the book presents the subject of sound engineering specifically as it applies to the motion picture art, it is of course valuable to anybody working with sound equipment regardless of its application.

300,000 OPERATIONS
AND STILL IN GOOD WORKING CONDITION
This veteran served five years on a heat recovery line, being partially opened and closed every four minutes seven hours a day for five years—exceptional service even from a valve of exceptional quality. A tribute to the practical applications of Crane research.



". . to unearth new facts"

Recently, the newly completed CraneResearchLaboratories, housing the largest and best equipped research facilities in the industry, were opened to public view. In the foreword of a booklet published on this occasion, President Charles B. Nolte says:

"Research is misunderstood by a great many people, but in its simplest form it may be defined as an organized and diligent application of existing knowledge to unearth new facts. . . . Crane Co., therefore, is dedicated to the philosophy that only through continuing a well-organized program of research can it best serve its employees, its stockholders, the users of its products, and society in general."

TRANSLATING RESEARCH INTO DOLLARS FOR YOU

Crane research has as its objective the saving of dollars in your plant operation—the improvement of those valves and fittings whose responsibility it is to control all phases of flow.

Research in design and in new alloys has resulted in multiplying the life of valve stems—this improvement translated into longer life means dollars for you. Valve seats have greater resistance to erosion and corrosion because of research—and again research cuts your costs—saves you money.

Alloys have been developed capable of withstanding the searing cold of 150 degrees below zero—the scorching heat of 1300 degrees above, opening up new fields for you in the handling of liquids or gases at greater ranges in temperature. And in welding new alloys, Crane research has developed new techniques that make their use practical. Again this means increased production—more dollars in profit for you.

But research does not stop with these spectacular achievements . . . it also provides an accurate control of manufacture that guarantees the uniform, high quality of the valves and fittings you buy from Crane.

CRANE

CRANE CO., GENERAL OFFICES
836 S. MICHIGAN AVE., CHICAGO

VALVES • FITTINGS • PIPE
PLUMBING • HEATING • PUMPS

NATION-WIDE SERVICE THROUGH BRANCHES AND WHOLESALERS IN ALL MARKETS

Power Plant Construction News

Fla., Orlando—Florida Public Service Co., East Central Avenue, plans improvement in steam-electric generating plant at Avon Park, including installation of additional equipment. Proposed to carry out work early in 1939.

Ga., Dahlonega—Southern Mining & Power Co., Dahlonega, plans power plant in connection with new mill and other buildings at local mining properties. Company is arranging a stock issue to total $350,000, a portion of proceeds to be used for work noted and development of mines.

Ill., Chicago—R. R. Donnelley & Sons Co., 350 East Cermak Road, plan installation of electric power equipment in new two-story and basement addition to printing plant on Twenty-first Street, designed for heavy-duty operation. Entire project will cost close to $400,000. Albert Kahn, Inc., New Center Building, Detroit, Mich., is architect and engineer.

Ill., Chicago—Hump Hairpin Mfg. Co., 1918 South Prairie Avenue, plans installation of electric power equipment in new three-story and basement addition to wire goods-manufacturing plant. Cost reported close to $100,000. Proposed to begin work soon. Alfred S. Alschuler, 28 East Jackson Boulevard, is architect.

Ill., Elgin — Winnebago Distillery Co., 105 West Monroe Street, Chicago, Ill., plans power house for operating service at new distilling plant on site near Elgin, recently acquired. Electric power equipment will be installed in main distillery and auxiliary structures. Entire project will cost close to $750,000. Paul Gerhardt, 457 West Fullerton Avenue, Chicago, is architect.

Ind., Indianapolis — Pitman-Moore Co., 1220 Madison Avenue, plans installation of electric power equipment in new addition to drug and chemical plant, for which superstructure will soon begin. Cost estimated close to $300,000.

Iowa, Waterloo—Rath Packing Co., Waterloo, plans installation of electric power equipment in new five-story addition to meat-packing plant, for which superstructure will begin soon. Entire project will cost over $300,000. Henschien, Everds & Crombie, 59 East Van Buren Street, Chicago, Ill., are consulting engineers.

Ky., Owensboro — Glenmore Distilleries Co., 660 South Fourth Street, Louisville, Ky., plans installation of electric power equipment in connection with rebuilding of distilling plant at Owensboro, recently damaged by fire. Loss included several one and multi-story buildings, totaling over $1,000,000.

Md., Baltimore—Consolidated Gas, Electric Light & Power Company, Lexington Building, has authorized expansion in Westport steam-electric generating plant, including installation of a new 33,000-hp. steam turbo-generator unit and accessories, high-pressure boilers and complete auxiliary equipment. Work is scheduled to begin soon and will be carried out during 1939. Cost about $3,500,000.

Mass., Quincy—Proctor & Gamble Co., Gwynne Building, Cincinnati, Ohio, plans installation of electric power equipment in new branch soap-manufacturing plant at Quincy, where tract of about 10 acres of land has been purchased. A power house will be built for factory service. Entire project will cost approximately $1,000,000. Proposed to begin work early in 1939.

Mich., Detroit — Detroit Sulphite Pulp & Paper Co., 9125 West Jefferson Street, plans installation of electric power equipment in new one-story addition to mill. Bids on general erection will be asked early in January. Cost reported over $85,000. H. R. Telfer is president.

Mich., Detroit—Hinde & Dauch Paper Co., Sandusky, Ohio, plans installation of electric power equipment in new one-story branch plant, 200x510 ft., on West Chicago Avenue, Detroit, where site was acquired recently, to be used for corrugated container manufacture. Work will begin early in 1939. Cost estimated close to $500,000.

Mich., Detroit—K. Shapiro, Inc., 1533 Winder Street, meat packer, plans installation of power equipment in new one-story plant on East Vernor Highway, 100x230 ft. Cost about $65,000. Proposed to begin work early in 1939.

Mo., St. Louis—National Vendors, Inc., 5149 Natural Bridge Avenue, plans installation of electric power equipment in new two-story and basement addition to vending machine-manufacturing plant, for which superstructure will proceed at once. Cost over $65,000.

Neb., Omaha—Table Supply Meat Co., 1211 Howard Street, plans installation of power equipment in new addition to meat-packing plant, on which work is scheduled to begin early next spring. Cost reported close to $60,000. Henschien, Everds & Crombie, 59 East Van Buren Street, Chicago, Ill., are consulting engineers.

N. Y., New York—National Gypsum Co., 190 Delaware Avenue, Buffalo, N. Y., plans installation of electric power equipment in connection with expansion and improvements in gypsum plaster and building products mill at East River and East 150th Street, Bronx, New York. Entire project will cost about $900,000. D. F. Hunt is chief engineer, first noted address.

N. C., Durham—American Tobacco Co., 111 Fifth Avenue, New York, N. Y., plans installation of electric power equipment in new five-story and basement addition to plant at Blackwell Street and Morehead Avenue, Durham, for which superstructure will be placed under way at early date. Entire project will cost close to $500,000. Francisco & Jacobus, 511 Fifth Avenue, New York, N. Y., are architects and engineers.

N. C., Lumberton—Jennings Cotton Mills, Inc., and Mansfield Mills, Inc., Lumberton, associated interests, plan installation of electric power equipment in connection with expansion and improvements in both properties. Cost over $300,000. Proposed to begin work soon.

Ohio, Amherst — Village Council plans early call for bids for new municipal electric power plant, with installation to include two 345-kw. and one 125-kw. Diesel engine-generating units and auxiliary equipment. Cost about $145,000. Floyd G. Browne, Marion, Ohio, is consulting engineer.

Ohio, Cincinnati—Cincinnati Milling Machine Co., Marburg and South Streets, plans installation of power equipment in new addition to machine tool plant, totaling close to 100,000 sq. ft. of floor space. Cost reported over $200,000. Carlton E. Brown is company engineer.

Pa., Clairton—Pennsylvania Industrial Chemical Co., Clairton, plans installation of electric power equipment in connection with rebuilding of portion of local plant, recently destroyed by fire. Loss estimated over $200,000. R. W. Ostermeyer is president.

Pa., Oil City—Continental Can Co., 100 East Forty-second Street, New York, N. Y., plans installation of electric power equipment in new one-story plant, 160x400 ft., at Mineral and West First Street, Oil City, where site was acquired recently. Entire project will cost about $500,000.

Texas, New Braunfels—Lone Star Wool & Mohair Mills, Inc., Krause Building, H. A. Wagenfuer, president, plans installation of electric power equipment in connection with expansion and improvements in local woolen mill. Entire project will cost close to $250,000. Work will be carried out early in 1939.

Va., Bland—Mountain Empire Hosiery Mills, Inc., care of Homer K. Bowen, Wytheville, Va., recently organized by Mr. Bowen and associates, with capital of $1,000,000, plans installation of electric power equipment in group of new mills to be built in Southwestern part of State, with first mill to be located at Bland. Entire project will cost over $500,000. Percy S. Curry, Wytheville, is interested in new company.

Va., Hopewell — Hercules Powder Co., Delaware Trust Building, Wilmington, Del., plans installation of electric power equipment in new addition to mill at Hopewell for production of ethyl-cellulose. Work will comprise several one and multi-story buildings, entire project reported to cost in excess of $600,000. Proposed to begin work soon.

Va., Winchester—Consumers Utilities Co., Winchester, plans extensions and improvements in artificial gas plant, including installation of additional equipment to double present capacity. Cost reported over $65,000. E. C. Goss is general manager.

Wis., Boscobel — Tri-State Power Co-operative Association, Boscobel, plans new steam-electric power plant on site now being selected in Southern part of State, to be used for power supply for rural electric system. Cost reported close to $100,000. Financing will be arranged through Federal aid. Wisconsin Development Authority, Tenney Building, Madison, Wis., is engineer.

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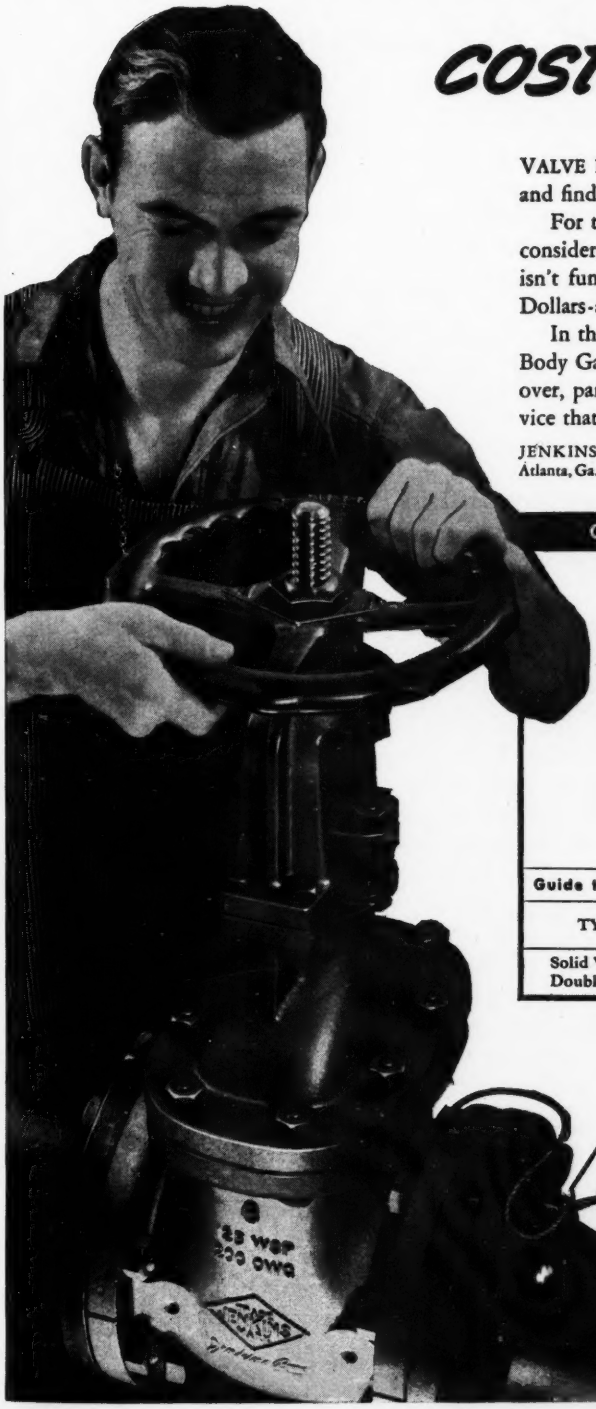

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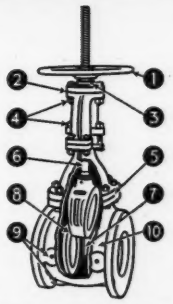

Guide to Figure Numbers of Jenkins O. S. & Y. Iron Body Gate Valves

TYPE	125 Lbs. W. S. P.		175 Lbs. W. S. P.		250 Lbs. W. S. P.	
	Scw.	Flg.	Scw.	Flg.	Scw.	Flg.
Solid Wedge . . .	650	651	277	253	204A	204
Double Disc . . .	874	875	—	—	878	879

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